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Topics of the Month

Geothermal power progress in New Zealand

A PRELIMINARY report and estimate of cost for a geothermal power station at Wairakei in the centre of the thermal area in the North Island of New Zealand, with an initial capacity of 20,000 kw., is to be prepared as quickly as possible by the English consulting engineers, Messrs. Merz & McLellan, London, who have been appointed as consultants on geothermal steam by the New Zealand Minister of Works.

The Minister has said that the consultants will also assist the Government's engineers in examining the proposal to produce heavy water by means of geothermal steam and will advise on technical questions that might arise from time to time in connection with investigation and use of geothermal steam.

Messrs. Merz & McLellan have agreed to send to New Zealand the head of their development department, a specialist in this field of engineering, to initiate the survey. They have been asked to avail themselves of Italian experience and this they are well equipped to do if necessary, having not only a personal knowledge of the work at Lardarello but also Italian associates.

Reviewing the work already done at Wairakei, the Minister said the conclusions reached after early investigations were most encouraging and it was decided to check the feasibility of electric-power production by drilling more holes in the hottest part of the area with the object of finding steam capable of producing power of at least 20,000 kw.

This objective has now been reached and it is certain that 20,000 kw. of power can be obtained from shallow holes. Holes to depths of 2,000 ft. and 3,200 ft. have been drilled and a third hole is being drilled. Equipment is now being prepared to test the yield of steam from the greater depths. It is undoubtedly much greater than that of any of the shallow wells. One of the largest shallow wells was recently measured and proved to be discharging steam equivalent to 4,000 kw. The deeper holes of larger diameter and nearly twice the cross-sectional area discharge at a substantially greater pressure, so that it is not unreasonable to believe that the discharge may produce power of about 10,000 kw. for a single hole.

The steam discharging from the holes at Wairakei usually contains a large amount of water. Nevertheless, almost complete separation of the steam from the entrained water has been proved to be entirely practicable.

The maximum power potential of the Wairakei area is, of course, not definitely known, but the Department of Scientific and Industrial Research in a recent report stated that at least 70,000 kw. could be expected from shallow holes in the area.

The appointment of consultants will enable a definite proposal for a steam power station to be prepared. While a capacity of 20,000 kw. is contemplated at the outset, the size of the station might be modified to fit in with the plans for a heavy-water plant. These are being prepared by the Atomic Energy Research Establishment at Harwell, with whom the consultants are to collaborate.

Cyclised rubber

TWO products which can be obtained from the reaction of natural rubber with chemicals are transparent wrapping film, produced by the hydrochlorination of rubber, and chemical-resistant paints based on chlorination products of natural rubber. The processes involve the treatment of rubber in solution in organic solvents. Until recently it was only by using such a technique that reactions involving acids could be carried out.

Now, however, the availability of new surface-active agents has led to the discovery that rubber latex can be so stabilised as to be capable of acidification with hydrochloric acid, sulphuric acid, etc. This discovery, made almost simultaneously in the laboratories of Rubber-Stichting in Holland and the Dunlop Rubber Co. in England, has opened up possibilities which ten years ago could hardly be envisaged. The mechanical breakdown of the rubber and its solution in expensive organic solvents is eliminated and the latex, by simple addition of the special stabiliser, can be treated with the reagent so that the particles of rubber in dispersion become chemically modified. The product is called cyclised rubber and it is claimed to be a worthy alternative to the high styrene-butadiene resin at present so popular in America. Although many other uses are envisaged, present work is concentrated mainly on its development as a shoe-soling material. A pilot plant set up in Malaya by Rubber Technical Developments Ltd. is producing cyclised rubber on an expanded experimental basis. The plant has been installed on the experimental estate of the Rubber Research Institute of Malaya, at Sungei Buloh. Enthusiastic reports have been received from footwear manufacturers to whom samples have been sent for testing. The cyclised rubber has been found to be many times tougher than leather, with a correspondingly longer life. It can be worked in the same way, with the additional advantage that it can be moulded. It is believed that it will eventually be cheaper than leather to produce.

In an article in *Rubber Developments* Dr. C. M. Blow describes how the latex stabilisation technique has been applied to the preparation of cyclised rubber. Heavy machinery is dispensed with and the product is obtained in a finely divided form which can be incorporated with untreated latex; the mixture is co-precipitated and a master batch of cyclised rubber, well dispersed in natural rubber, is produced. This material can be mixed subsequently with further rubber and compounded with vulcanising ingredients and fillers to impart special properties. In this form, after vulcanisation, the cyclised rubber is found to produce considerable reinforcement, i.e. stiffening of the rubber without loss of tensile strength. It is believed that this reinforcement of the rubber arises from the high degree of dispersion that is possible by co-precipitation from aqueous dispersion and also from the fact that, since the rubber is reacted in latex form, the breakdown of molecule length, which is involved in the treatment in solid or solution form, is largely avoided.

Chlorine and quicksilver

AS pointed out by Mr. L. R. Thomas in his article on Chlorine production trends in last month's *CHEMICAL & PROCESS ENGINEERING*, in recent years there has been increasing use of the mercury cell. Even in the U.S., where the diaphragm cell has reached a high efficiency, the mercury cell has been used in many new chlorine plants since the war. This demand has in the past made mercury

scarce and dear. Now the immediate post-war expansion of chlorine capacity has been completed and the demand is falling, especially as large stocks of mercury have been accumulated in the U.S. So marked has been the drop in demand that some trade circles in New York think that consumption will soon be 40 to 50% below what it was a year ago. They predict further that the annual rate of consumption in the U.S. will finally settle down to 45,000 flasks (1 flask = 75 lb.). This quantity could be supplied by domestic producers and by Mexican and Yugoslavian suppliers who are delivering about 12,000 and 15,000 flasks p.a., respectively. Thus the prospects for Spanish and Italian suppliers in the American market are poor. However, as they have accumulated good reserves from high profits in the past, it is not thought likely that they will try to compete by drastically cutting prices. The chances are that they will keep their stocks against the possibility of an increase in demand in the future. If the use of the mercury cell for chlorine production increases on the scale envisaged by Mr. Thomas, there should be no difficulty in disposing of mercury in the world markets.

Pile processed plastics

IRRADIATION of polythene, *Perspex* and other plastics in an atomic pile can alter their properties to a remarkable degree. This work, which may result in the production of new engineering materials, has been done by Dr. Arthur Charlesby and his associates at the Atomic Energy Research Establishment, Harwell, and it is causing wide interest, particularly in America. Irradiation of polythene alters its heat stability, solubility and mechanical properties by causing cross linking of the molecules. It also reduces the degree of crystallinity present at room temperature; the Harwell scientists have produced a range of materials varying from a largely crystalline structure to one which is entirely amorphous, even at room temperature. Ordinary polythene is severely attacked by boiling sulphuric acid, but the irradiated plastic is attacked only on the surface. Similarly, the attack of aqua regia at 100°C. is largely limited to the surface of the modified polythene. Polythene's resistance to organic solvents is also increased to an astonishing extent by irradiation. Another property conferred by irradiation is what Dr. Charlesby calls the 'memory phenomenon.' A piece of treated polythene can be compressed like rubber into any shape and it will retain this on cooling. When warmed again, however, it will revert to its original shape. This may prove very useful for getting plastic components of machines into otherwise inaccessible positions.

Irradiation of *Perspex* (polymethyl methacrylate) causes it to acquire a foamed structure. Foamed *Perspex* is eight times lighter than the untreated polymer and it has higher electrical resistance, suggesting possibilities as an insulating material. Readers interested in the chemistry of the process should read the article by Dr. Charlesby and his collaborator, Maurice Ross, in the August issue of our associated journal *Atomics*. They describe how irradiation causes internal bubbling in the plastic and suggest that this is due to the decomposition of the side chains of the polymer, liberating gases which, at a suitable temperature, can diffuse into bubbles. Bubbles do not occur within a distance of 1 mm. from the surface of the plastic owing to the diffusion of the decomposition products to the surface. This means that the foamed plastic has a tough skin.

Nylon, polystyrene, polyvinyl alcohol, polyvinyl chloride, and *Carbowax* have all been successfully cross-linked by

irradiation. Polythene, rubber and other long chain materials can be cross-linked with pure gamma and x-rays and electrons from a linear accelerator, as well as by irradiation in the pile.

The Americans seem more interested in the industrial possibilities of irradiated plastics than the British. Will this be another case of a British discovery having to be sent abroad for its industrial exploitation?

Wanted: food preservation engineers

AGRICULTURAL engineering is now a recognised branch of the profession. It is becoming increasingly realised that the agricultural engineer has just as important a task as the biologist or the chemist in increasing food production. On the other hand, food when grown has to be preserved or processed and the prevention of waste and spoilage is almost as important as production. In this field the work of the biochemist and bacteriologist is recognised, but the activities of the engineer in food processing and preservation receive scant attention.

Research on these problems began in Britain during the 1914-18 war. Until 1939 the prime need in food preservation was for more biochemical and bacteriological knowledge. In many respects refrigeration practice had run ahead of scientific knowledge of the behaviour of foodstuffs during freezing and cold storage. During this period techniques in this field were greatly improved as a result of research. The carriage of fruit and meat from overseas are notable examples.

The adoption of new processes such as dehydration, quick freezing and low-temperature cold storage was greatly accelerated by the second world war. The lack of the kind of knowledge needed to turn laboratory experiments into industrial processes was then all too apparent. With a few notable exceptions, design of equipment is empirical or traditional, and often both efficiency and hygiene leave something to be desired.

Very few data exist upon which rational design of food-processing plant can be based. The designer of equipment for food processing and preservation must not only have the necessary mechanical and chemical engineering knowledge, but must understand the biochemical considerations governing the process. Research and development work is largely a matter of discovering the limits of the process variables within which the specifications laid down by the food scientist can be met, and of providing data to enable the designer to choose the optimum conditions within those limits. Fundamental researches in such fields as heat and water transfer also have to be undertaken. For instance, biochemists have laid down that, in order to retain initial quality in frozen fish, the freezing time must not exceed a certain limit. The engineers have not only to define the limits of shape, thickness and surface heat-transfer rate which will produce this result, but have to investigate the effect of refrigerant flow rate, turbulence, viscosity, etc., on the heat-transfer coefficients, and must also explore the mathematics of heat flow in freezing bodies.

Since the war research engineers have joined several organisations dealing with food processing and preservation. The Research Association of British Flour Millers and the British Food Manufacturing Industries Research Association now have engineering research staff, as has the National Institute for Research in Dairying at Shinfield and the Ditton Laboratory at East Malling. Several of the larger firms have also recruited research engineers and the Ministry of

Food Experimental Factory at Aberdeen has also done so.

Perhaps the most notable advance in this field is at the Torry Research Station. Among the contributions which the engineering research and development section has contributed is a vertical-plate freezer, specially developed to freeze the early part of the catch on board existing trawlers.

Other activities in the six years of the section's growth have been the specification of a new trawler for the station and the design of a new set of experimental cold stores. The trawler is the first diesel-electric vessel of its kind, and the cold stores incorporate many novel features, including jacket cooling. A new building to accommodate the research on quick freezing and cold storage is being erected at Torry. A well-equipped engineering workshop is already in being.

Besides the problems mentioned, the long-term programme at Torry includes a study of cold-store design with special reference to humidity, the study of heat leak into trawlers' holds, development of improved materials and equipment for trawlers' holds, and the development of gutting machinery for white fish.

The promotion of physics and engineering research in food preservation is clearly a matter of real importance to government. To assist in promotion, to study where effort is required or gaps need filling, a joint committee of the D.S.I.R. and the Ministry of Food has been set up. Representatives of important industrial groups and food research establishments serve on this committee. This is one of the methods employed in drawing the attention of the engineering profession and the food-processing and -preservation industries to the need for food-preservation engineers.

Tonnage titanium

THE largest project so far undertaken in the United States' titanium expansion programme was started recently when the Defense Materials Procurement Agency signed a contract with Cramet Inc., of Chicago, for the production of titanium sponge. The company, a wholly-owned subsidiary of the Crane Co., is to build a plant with a capacity of 6,000 tons p.a., which will start up early in 1955 and be in full production a year later. It will produce ingots of titanium and titanium alloys as well as sponge. Most of the cost of the plant, about \$25 million, will be covered by an advance from D.M.P.A. to Cramet, to be repaid with interest as titanium sponge is produced. During the five-year term of the contract the U.S. Government has an option to buy 7,500 tons of sponge and, on the other hand, an obligation to buy 6,000 tons if tendered by the company. The price is to be \$5/lb. during the first year of production and \$4 thereafter.

Two other companies already have contracts with the D.M.P.A.: Titanium Metals Corporation of America with a capacity of 3,600 tons p.a. of sponge, and E. I. du Pont de Nemours & Co., who are increasing their capacity from about 900 tons p.a. to 3,600, beginning in 1955. To increase production of titanium raw materials, du Pont are building a \$3 million ilmenite plant at Lawtey, Florida, which should be working early in 1955 with an output of about 100,000 tons p.a.

With the new Cramet project, the U.S.A. will have a total capacity of 13,200 tons p.a. of titanium sponge by 1956, not counting the output of the research facilities of the Bureau of Mines. The Office of Defense Mobilisation has announced a revised expansion goal for titanium sponge of 25,000 tons p.a. by 1956—an increase of 3,000 tons over the October 1952 target. This is not a realistic estimate of

actual production, but is the sum of the maximum output of all possible projects.

Further American progress in titanium is the development by the National Research Corporation of a method of producing cast shapes of titanium metal. Castings of both pure and alloyed titanium, of complex shape and weighing up to several pounds, have been produced in pilot quantities. The content of carbon, oxygen and nitrogen is reasonably comparable with that of commercial wrought titanium, and the surface attainable is said to equal that of good sandcast metals. This development owes its origin to the Department of Defense policy of encouraging private industry to employ its own funds to develop techniques and products to a point where the military can procure material on a purchase-order basis. National Research is now under contract to supply pilot titanium castings to the U.S. Army.

Honouring a pioneer

MANY chemical engineers regard George Edward Davis, who died 47 years ago at the age of 57, as the pioneer of the profession. Davis lived and worked during those momentous years when the foundations of the modern chemical industry were being laid in the twilight of the Leblanc soda process. He had a profound knowledge of this process and took out four patents for making chlorine from the hydrochloric acid by-product. His pioneering 'Handbook of Chemical Engineering' contained much information on the working and designs of the Leblanc process. The Handbook was more or less the culmination of his life's work for the first edition appeared only five years before his death. Preceding this were many busy years in the chemical industry as a consultant and educator.

Davis's memory has now been honoured by the Institution of Chemical Engineers, who last month organised the George E. Davis Memorial Lecture. It was given on October 10 at the Reynolds Hall, Manchester, by one of the pioneer's assistants, Mr. Norman Swindin, who, now 73, can himself look back on a full life devoted to British chemical engineering.

Mr. Swindin recalled that one of Davis's earliest activities was the erection of one of the first by-product gas plants for the extraction of hydrocarbons and sulphate of ammonia at the Rockingham works of Newton Chambers. This he did before he was twenty. For the next ten years he worked in the soap and alkali industry and then, at the age of 30, he started private practice as a consultant in Manchester. For a short time he was an alkali inspector and his reports reflected his energy, fairness, sense of justice and thoroughness, and his intense irritation at the disgusting methods of management he often found. This experience coloured much of his later practice and influenced his efforts to prevent air and river pollution, no doubt giving rise to his quest for the chemical engineer. In these years he delivered a course of lectures on chemical engineering at the Manchester Technical School and these lectures, intensely sound and empirical, formed the basis of the Handbook.

Davis was essentially an educator, constantly lecturing and writing on the chemical industry and chemical engineering. His work can be regarded as having crystallised the vague consciousness of the need for an engineer to design chemical plant which existed long before his time. He was careful to separate chemical technology and applied chemistry from chemical engineering, realising that the latter is common to the whole range of manufacturing chemistry. In fact, he perceived the modern conception of chemical

engineering as a series of unit operations for carrying out chemical reactions in a whole range of industries. His reputation rests securely on his work in technical education and in laying the foundations of chemical engineering. The Institution have done well to honour his memory.

Making the most of manganese

INFORMATION supplied by member countries of the Organisation for European Economic Co-operation indicates that the supply of manganese continues to cause some concern in Western Europe and that, under the pressure of economic conditions and owing to the high price of manganese ore, special attention has been given to the conservation of manganese by all the principal users of this material.

To a very large extent in certain countries the manganese requirement of the blast furnaces in making pig-iron is now met by the use of local ores, imported low-grade ores, or slags, and the imports of high manganese ores are practically confined to the manufacture of ferro-manganese. In addition, the main use of the manganese-bearing indigenous ores is to impart a relatively high manganese content to that proportion of the pig-iron which is used for open-hearth steel-making. In several countries, this manganese content of the pig-iron is adequate to supply the manganese required in steel-making up to the finishing stage and in consequence the use of the imported rich manganese ores and of ferro-manganese is restricted to that required to give the finished steel its desired specification. In these circumstances, it would be difficult to foresee any marked reduction in the requirement of manganese unless there is a drastic change in steel specifications.

Some possible methods of further economy are described in a new O.E.E.C. book, 'Manganese in the Iron and Steel Industry' (3s. 6d. net). It will be generally accepted that practically the whole of the manganese present in the pig-iron used in the Bessemer or electric arc processes is lost during the oxidising period of the steel-making, and, to this extent, any reduction in the manganese content of the pig-iron used would represent an economy. At the present time, the main purpose of the manganese-bearing ores used in the blast furnace making pig-iron for these processes is to attain the desired sulphur content. Attention should be given to the possibility of reducing the amount of manganese ores thus used, and maintaining the desired sulphur content of the pig-iron by the use of one of the well-established methods for desulphurising the iron.

While many of the manganese-bearing local ores are unsuitable for the manufacture of ferro-manganese, it may be possible to concentrate the use of these ores in furnaces making spiegel and pig-iron for the open-hearth processes and thereby enhance the manganese content of this type of iron. In any case attention is drawn to the desirability of reserving high-grade manganese ore for the production of ferro-manganese. Where it is necessary to enrich blast-furnace burdens, therefore, this should be done with the lean indigenous ores, and by using the highest possible proportion of manganese-bearing slags.

Account must be taken also of a process used in Germany whereby an increased yield of manganese in the production of ferro-manganese in blast furnaces may be procured by control of the composition of the slag. Finally, emphasis is laid on the importance of extending the practice of sintering ore fines before charging into the blast furnace, as this often helps to eliminate sulphur content. This is bound to produce savings in the use of manganese in steel-making.

SMOKELESS FUEL MANUFACTURE

Plants and Processes for Carbonising Briquetted Coal

By R. J. S. Jennings, M.A.(Oxon.), A.R.I.C.

(National Coal Board)

Modern mining methods result in the production of an increasing amount of fine coal, and briquetting this coal and carbonising the resulting briquettes at low or medium temperature is one of the chief ways of putting it to use. The process can be applied to low-rank coals and is complementary to high-temperature coke manufacture inasmuch as non-coking coals may be used. In this survey the author covers fairly recent low- or medium-temperature coal briquette carbonisation practice in Britain and abroad (except America*) and shows what use has been made of the carbonisation products.

The 'Phurnacite' process

PHURNACITE is a high-quality domestic fuel consisting of carbonised ovoid-shaped briquettes of from 33 to 35 g. The carbonised ovoids are very hard indeed, difficult to break and therefore easy to handle. Their specific role is as a smokeless fuel in closed types of domestic appliances and they are therefore competitive with graded anthracite fuel.

In Britain, *Phurnacite* has been produced since about 1942. Recently the original plant was enlarged to produce about 300,000 tons a year of saleable fuel.

The plant, the only one of its type in the world, is situated at Aberaman in South Wales and the process consists of briquetting local fine coals with pitch as a binding medium and carbonising the resulting ovoids. (Figs. 1 and 2.) Besides *Phurnacite*, tar and gas are formed as by-products.

The original plant was completed in 1942 by Powell Duffryn Ltd. The French Districoke Co., who built a somewhat similar, but now inoperative, plant at Noeux les Mines in the Pas de Calais, had agreed to supply the ovens, while the briquetting section was to be built by Powell Duffryn Ltd. A large proportion of the equipment could not be sent from France because of the war, but Powell Duffryn Ltd. employed what materials were available and continued with the erection of the plant.

In 1947 the plant, together with the coke ovens, central tar plant, etc., became a unit of the Carbonisation Department of the South Western Division of the National Coal Board. A fairly detailed description of the Aberaman plant appeared earlier this year.¹

The ovens, of the recuperative type,

*In the United States the National Fuels Corporation of New York is the only company which has achieved anything of note in this field. However, their pilot plants at Bethlehem, Pa., and New Haven, Conn., have been shut down and are being dismantled. A pilot plant to make 10 to 15 tons/day of smokeless fuel is to be erected at Linden, New Jersey, where the Chemical Construction Co., a subsidiary of American Cyanamid, has a works.

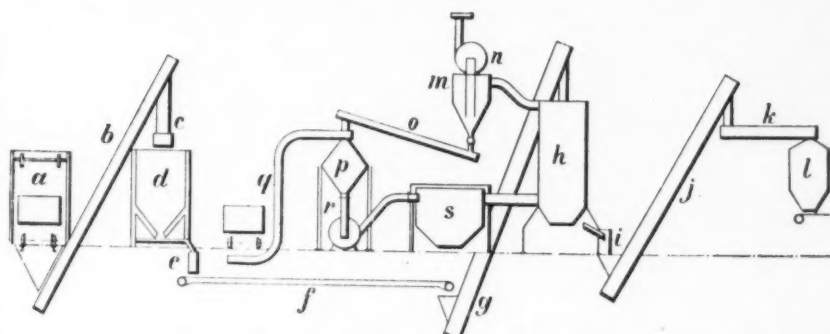
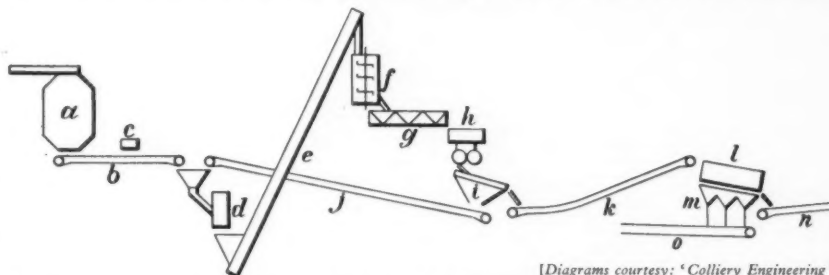


Fig. 1. Flow diagram of coal drier section of the N.C.B. Phurnacite plant at Aberaman, showing pulverised coal-fired drying furnace. (a) Wagon tippler. (b) Wet coal elevator. (c) Wet coal scraper. (d) Wet coal bunkers. (e) Wet coal scraper conveyor (f) Wet coal conveyor. (g) Wet coal elevator and drier. (h) Drier. (i) Dry coal scraper. (j) Dry coal elevator. (k) Dry coal conveyor. (l) Dry coal bunker. (m) Cyclone. (n) Fan. (o) Dust conveyor. (p) Pulverised coal bunker. (q) Pulverised coal conveyor. (r) Pulverised coal mill. (s) Furnace.



[Diagrams courtesy: 'Colliery Engineering']

Fig. 2. Flow diagram of briquetting section of the Phurnacite plant. (a) Dry coal bunker. (b) Coal measuring belt. (c) Pitch. (d) Mixture disintegrator. (e) Mixture elevator. (f) Pug mixer. (g) Cooling worm. (h) Roll press. (i) Shaker screen. (j) Rejects and fines belt. (k) Chain conveyor. (l) Trommel screen. (m) Fines bunker. (n) Raw ovoids belt to ovens. (o) Fines conveyor return to process.

consist of two batteries of 40 built according to the Districoke Co.'s design. They are heated with recycled oven gas, have parallel walls, vertical flues, and the oven floors are inclined to the horizontal. The raw ovoids are charged in at the top of each oven and, after about 4 hours' carbonisation, the bottom door is removed and the hot ovoids are discharged down the slope into a quenching car. The throughput for the two batteries is about 1,000 tons/day of raw ovoids.

It has been reported from Holland that plants similar to the *Phurnacite* plant are

being contemplated by the Dutch State Mines in Limberg.

The Carmaux process

This process for producing smokeless fuel is in operation at Carmaux in southern France. Ovoids consisting of coal slack briquetted with coal tar pitch as binder are subjected to a preliminary treatment by heat for the purpose of producing a thin outer coke skin around them so that, when they are transferred to an externally-heated vertical metal retort, the ovoids will not soften or clog together.

Georges² states that the coal used is 6-mm. size, having 25% volatile matter and 10% ash; 6% of pitch is added to make the ovoids.

Thau³ says that the preliminary treatment is carried out in a vertical chamber furnace as used in gas works (see Fig. 3). The chambers are made of steel plate and are heated by means of longitudinal channels in the long sides of the furnace; in order to be able to adjust the temperature, a kind of 'central-heating circuit' is formed by mixing flue gas with the hot air in the heating channels, which are not visible in the illustration. Apart from this, the construction of the installation hardly differs at all from the normal type as used in gas works.

The raw briquettes, made from bituminous coal, are fed into the feed hopper *a*, whence they pass into the cylindrical apparatus *b* in which they are pre-treated; from time to time the content of this cylinder is allowed to fall into the low-temperature (L.T.) carbonisation chamber. The combustion gases pass from the exhaust through the vertical channels *c* into the piping *d* and are then aspirated by means of the fan *e* through the charge in the cylinder *b*. At the same time air is blown into the flue gas through the fan *f* and the pipe which is inserted (like an injector) in the tube *d*; this subjects the briquettes in the cylinder *b* to a certain degree of oxidation, in addition to the pre-heating. The branch pipes *h* feed hot flue gases through the steam boiler *i* and the steam raised in this boiler is led below, in the usual way, into the L.T. carbonisation retorts; here it improves the heat transmission by reason of its gas-flushing effect and also, by reason of its protective action, hinders the decomposition of the tar vapours on the walls of the L.T. carbonisation chamber; in addition to this it also cools the L.T. coke briquettes in the bottom of the plant.

The whole construction of the plant offers many possibilities of adjusting its operation. The briquettes are dried and hardened in the cylinder *b*, under the effect of heat and oxygen, and their outer surfaces lose their caking properties, so that during the L.T. carbonisation process which follows they no longer 'cake' together. Thus before the flue gases enter the container *b*, some 60% of air is added and the charge is treated at 250°C. for some 4 hr., the conditions of treatment being adjusted to suit the characteristics of the coal. The L.T. carbonisation chamber is emptied, one-third at a time, at intervals of 4 hr. and thereupon the contents of the container *b* are fed into the carbonisation chamber. The dimensions of the chamber are so chosen that it can contain three loads from the container *b*. The size of the wagon *k* indicates the quantity of L.T. coke briquettes discharged at the bottom of the plant as, after this wagon is filled, the charge has sunk to such an extent that the carbonisation

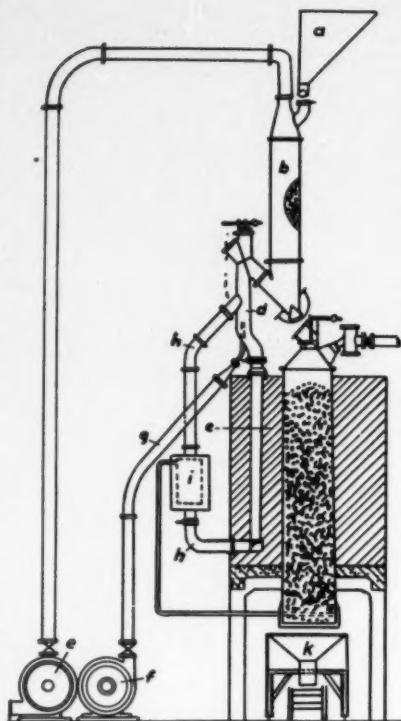


Fig. 3. Section through a vertical chamber furnace as used at Carmaux, France, for carbonising ovoid briquettes.

chamber can take up the briquettes contained in *b*. The period of L.T. carbonisation of the briquettes is three times as long as the period of pre-treatment. In this plant it is possible to treat briquettes made entirely of caking coal fines, in addition to those made by using pitch or some binding medium.

A group of 20 chambers (Fig. 4) can produce 100 tonnes/day of ovoids, says Georges.² A more detailed description of the Carmaux work is given by Beaugrand in a recent communication to the 4th International Congress of Industrial Heating.⁴

Possible French developments

In a communication of the French Coal Research Station,⁵ Salmon foresees the production of carbonised ovoids from Lorraine coals without the addition of a pitch binder. In order to get the coal particles to agglomerate, he suggests that either a suitable quantity of bituminous coal should be used to provide a paste on heating or else that a layer of paper should be made to adhere to the ovoid surface during moulding, thus conveying the necessary stability.

The starting material is a mixture of French coals described as 40 to 50% *flambant gras* and 60 to 50% *flambant sec* coal, which has been previously carbonised and brought to a volatile matter content of 6 to 8%. Non-carbonised *flambant sec* coal is put into the oven at the same time as the ovoids and fills the spaces between them. Thus carbonised ovoids and L.T.

carbonised *flambant sec* coal are obtained in one operation. The ovens are to be in groups of 3 or 6, and a battery of 60 ovens will make about 400 tonnes/day of carbonised ovoids (see Fig. 5). After quenching, the semi-coke will be sent to the briquetting plant, where it will be mixed with the necessary quantity of washed fines (*flambant gras*). The heat retained in the semi-coke will dry these fines and in due course a dry, cool mixture will result.

Since the ovoids leaving the presses will be relatively fragile, it will not be possible to build up a stock of them unless one obtains a press which will produce strong ovoids, so that a regular supply to the ovens may be maintained.

The Brennstoff-Technik process

A notable example of all-iron retorts is that constructed by Brennstoff-Technik and known as the B-T retort. Thau,⁶ describing the process, says that the coal is heated to 550 to 600°C. in iron chambers with parallel walls, the heating being by means of gas circulation outside the walls. In order to empty the chambers after the carbonisation process, the walls can be opened out, thus enlarging the chambers. Basically there is no limit to the height of the retort. The width of the chambers can be selected to suit the nature of the coal.

Lorenzen⁷ remarks that Brennstoff-Technik GmbH. have already tested their retorts in a number of trial plants, the most important one being at the Berlin-Neukölln gas works. Its capacity, in terms of small coal and briquettes, was as much as 50 to 60 tonnes/day. The plant was in operation from 1938 to 1944 and represented practical proof of the efficacy of the B-T process; indeed, such a large installation can hardly be classed as experimental.

Thau⁶ reports that the plant survived the war in good condition and was ready to be put into service as soon as the coal position should allow. Upper Silesian, Ruhr, Saar and Lorraine coals were treated in the preliminary trials. Tests using ribbed walls, which transferred the heat into the heart of the charge and at the same time considerably increased the heating surface of the chambers, produced a considerable reduction in the time of treatment and an increase in throughput. Investigations into the materials used to build the retorts showed that the operations did not affect their rigidity. This fact is important, since earlier L.T. carbonisation techniques involving the use of iron retorts fell down on the durability of the iron; it follows that this failure must have been due, not to the iron itself, but to incorrect handling during heating.

On conclusion of the trial and development work, it became clear that the B-T process for the L.T. carbonisation of bituminous coal in high-efficiency retorts was a success from both the technical and the economic points of view. These trials led to the placing of contracts for three large

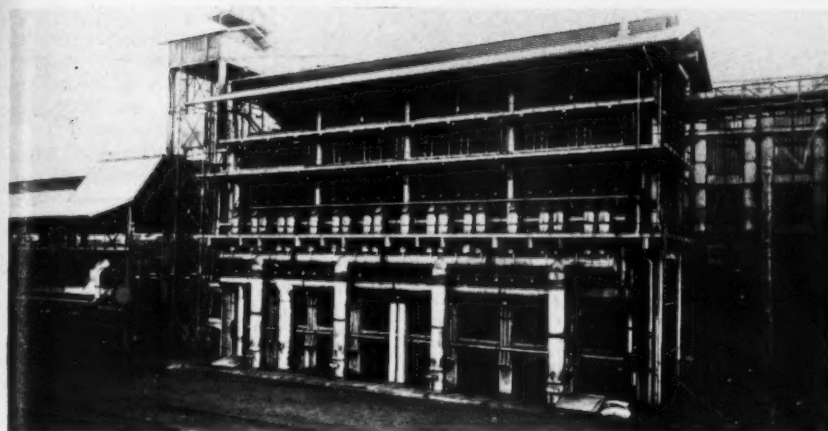


Fig. 4. A group of briquetting chambers at Carmaux.

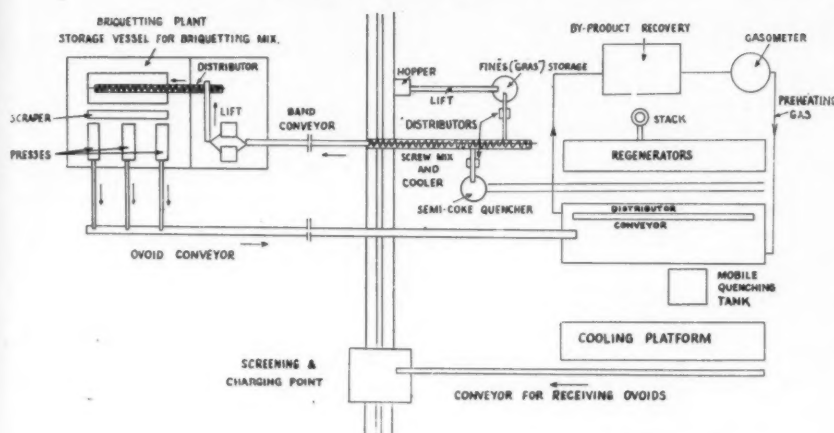


Fig. 5. Plan of a French plant to make about 400 tonnes/day of carbonised ovoids.

L.T. carbonisation plants, each with an annual capacity of 500,000 tonnes. One of these was to be in Polish Silesia and two in Marienau, in Lorraine, reports Lorenzen. At the end of the war work on these plants was suspended.

A detailed description of the Marienau plant, which had suffered war damage, is given by Georges.² The object of the plant was to produce 175,000 tonnes p.a. of 30 to 50 g. carbonised ovoids from 50 to 70 g. briquettes of cellulose sulphite-bound Petite Rosselle dry fines. In addition, there was to be fuel for mobile gas producers and tar for hydrogenation in the Ruhr.

Present development

In 1947 it became possible to re-erect a trial L.T. carbonisation retort which consisted of two L.T. carbonisation chambers of adjustable width. At present, it is being used to test the suitability of French and Saar coals for L.T. carbonisation. The results of the trials have led to the placing of an order for the construction of a plant with a capacity of 150 tonnes/day of wet coal or briquettes or, alternatively, of 90 tonnes/day of small coal. An experimental

retort similar to that in Marienau has been built for German use in Essen-Rellinghausen by the German Coal Mining Board.

The Krupp-Lurgi process

(a) **Applied to brown coal and lignite.** A process to obtain carbonised briquettes from brown coal and lignite, introduced by the Lurgi Co., uses a ring-roll press constructed by Krupp, the process being known as the Krupp-Lurgi process. The raw coal is dried while passing in counter-current through a stream of inert gas having a temperature of about 1,000°C. so that the fuel disintegrates instantly into powder, and in this state it is transferred to the press which continually exerts a pressure of 2,000 to 2,500 atm. upon the lignite. The hard and very dense briquettes so formed retain their shape (apart from shrinkage) while passing through the Lurgi oven, through which hot gases are circulated. Thau⁶ reports that, at the end of the last war, 22 of these Krupp presses were being operated in central Germany, and the production of briquetted semi-coke from lignite was 3,800 tonnes/day. Since then, however, all these presses have been dismantled by the Russians and

transferred to Russia. The Krupp-Lurgi process as applied to brown coal and lignite is fully described by Thau⁶ and Landwehr.⁹

Tests on semi-bituminous coal (from the Krupp collieries at Essen) with a pitch binder were conducted at the Krupp-Lurgi Dolni Rychnov plant, Bohemia, in 1942 and 1943.¹⁰

(b) **Applied to bituminous coal.** A Krupp-Lurgi plant has been built at Velsen in the Saar, not far from Marienau.² The process is fundamentally identical with the Brennstoff-Technik, but is on a reduced scale. During the war the plant produced 50,000 tonnes p.a. of marketable fuel, tar (some of which was used in the Ruhr to make diesel oil for submarines) and gas for oven heating. Georges² describes the carbonisation of tamped Velsen fines and compares the process with the Marienau B-T process. Ovoids from Saar and Moselle coals have been produced at Velsen, and further details of the Velsen plant are given,¹¹ but no information is found on the carbonisation of these ovoids.

The Lurgi Spülgas process

Carbonisation in this process is brought about by circulating hot gas ('Spülgas') around the charge. The process has been applied more to brown coal than to bituminous coal and has found wide application. In the British Zone of Germany, for example, the only L.T. plant working on brown coal is a modern one (built in 1936) at Schwelwerk Offleben near Helmstedt and this employs the Lurgi-Spülgas process.

A recent communication from Lurgi, in which it is stated that all existing plants except the one at Offleben are situated either in the Eastern Zone of Germany or in overseas countries, contains a list (Table 1) of Lurgi carboniser plants built up to 1945.¹²

Some description of Spülgas plants now lying in the Russian Zone of Germany has been given^{13, 14} and a list¹⁵ mentions their exact location. The tar made in all German Lurgi plants was the most important product, and the plants would never have been built had it not been for the Bergius hydrogenation process producing first-class motor spirit.

The Offleben plant^{16, 17}

Hot inert gases are used to dry the coal from 48% to about 12 to 13% moisture and coal of size 0 to 4 mm. screened for briquetting. The briquettes are produced in electrically-operated extrusion presses.

The retorting plant consists of 10 Lurgi-Spülgas units, each of capacity of 300 tonnes/day of briquettes. Each unit consists of two separate vertical shafts placed one on each side of central combustion chambers supplying the heating gases. Each half unit consists essentially of two portions mounted one above the other. The upper portion serves for briquette

Table 1. Lurgi Carboniser Plants built up to 1945

Country	Plants	Units	Coal, tonnes/day	Fuel	Production of tar, tonnes p.a.
Greece ..	1	2	100	Lignite	1,500
U.S.A. ..	1	2	350	Lignite	7,000
Canada ..	1	2	350	Lignite	6,500
England ..	1	1	125	Cannel coal	6,000
Korea ..	2	6	1,000	Sub-bituminous coal	30,000
Japan ..	1	4	700	Brown coal	25,000
New Zealand ..	1	2	300	Sub-bituminous coal	7,000
Germany, E.* ..	1	24	12,500	Brown coal	250,000
Germany, E.* ..	1	10	6,000	Brown coal	120,000
Germany, W.† ..	1	10	5,000	Brown coal	100,000
Germany, E.* ..	1	6	3,500	Brown coal	60,000
Germany, E.* ..	1	5	3,500	Brown coal	50,000
Germany, E.* ..	1	6	3,200	Brown coal	50,000
Germany, E.* ..	1	4	2,000	Brown coal	40,000
Poland ..	3	3	225	Bituminous coal	7,000
Germany, E.* ..	1	12	6,500	Brown coal	125,000
Czechoslovakia ..	1	40	10,000	Sub-bituminous coal	400,000
Japan ..	1	1	250	Bituminous coal	9,000
Germany, E.* ..	1	18	10,000	Brown coal	200,000
Germany, E.* ..	1	14	3,500	Bituminous coal	115,000
Germany, E.* ..	1	40	10,000	Sub-bituminous coal	400,000
Poland ..	1	6	2,000	Bituminous coal	70,000

* Eastern Zone

† Western Zone

drying, and the dried briquettes pass from the upper to the lower portion of the unit in which carbonisation is effected and in which the coke is cooled before discharge. The maximum temperature reached by the briquettes in the carbonisation zone is about 500°C. The process is practically self-supporting from the point of view of gas necessary for drying and carbonisation.

The resulting coke after 'ageing' and cooling is extremely reactive, and special precautions are necessary to avoid fires and explosions.

Some plants carbonising bituminous or sub-bituminous coal

Several trials have been made to subject pitch-bound ovoids to L.T. carbonisation in externally-heated metal retorts. Now, unless these ovoids are pre-treated in some way as, for example, in the Carmaux process, they tend to clog together, lose their shape and obstruct the retorts, owing to the pitch melting before the carbonisation temperature is reached.

A successful process to overcome these difficulties, used before and during the last war, was introduced by Weber who, dispensing with pitch, used a binder made from concentrated sulphite lye and an aqueous suspension of 1% fireclay, termed 'clay milk.' During the last war ovoids bound with this mixture were carbonised in Lurgi ovens at low temperature in large plants in Upper Silesia (now part of Poland) by blowing hot gases through the charges.⁸ The fate of these plants is not known.

The Spülgas process was applied to bituminous coal at Blechhammer in Poland, but this plant was dismantled by the Russians and transferred to Siberia. From slightly caking coal was made hard coke for transport producers and hydrogen; 4% sulphite lye and 2% pitch were used as binder, but it was doubtful whether the process was very economical.

Jones,¹⁸ manager of the New Zealand Lurgi-Spülgas plant carbonising Waikato slack to make semi-coke for briquetting, points out the following possibilities: By carbonising the ordinary briquettes made from carbonised coal in the Lurgi retort, it is possible to produce briquettes which would be smokeless and which would not soften on heating. Briquettes which are bound with pitch or bitumen retain their shape in the retort when they are mixed with the coal to be carbonised, and it is feasible to assume that briquettes amounting to at least 40% of the coal fed to the retort could be carbonised in this manner. The addition of, say, 10% of coking coal to the semi-coke before briquetting would increase the strength of the carbonised briquettes.

Low-temperature carbonisation of bituminous coal by hot sand

Using hot sand as a heat carrier, this process, due to Weber,⁹ has many of the advantages of Spülgas carbonisation, since in both cases the medium carrying the heat required for carbonisation is in close contact with the briquettes. Whereas in the Spülgas process as used until now the heating gases remain inseparably mixed with the gases and vapours released from the coal, the sand-carbonisation process enables a L.T. carbonisation gas to be produced having the same characteristics as that made in conventional L.T. ovens.

Various types of contemporary L.T. furnaces can be adapted for the sand-carbonisation process, but Weber chose the rotary tubular furnace as being particularly suitable, as it is very simply made, in addition to possessing a high output capacity and rigidity. A rotary carboniser using hot sand has recently been described by Pistorius of the Demag Co.¹⁹ Since the hot sand process is much more rapid than any other method of heat transmission in L.T. carbonisation processes, a rotary

tubular furnace about 6 m. long is quite sufficient. The carbonised briquettes can also be cooled in hot sand, thus avoiding the production of stresses in the briquettes (such as occur when they are quenched with water) and endowing them with greater strength. For all practical purposes, abrasion is non-existent during carbonisation or cooling in sand, and consequently the smooth surface of the carbonised briquettes so produced considerably helps to prevent further damage during transport. The following advantages are also claimed for this Weber process:

(a) Since the hot sand is in direct contact with the coal to be carbonised, there is very little strain on the walls of such types of furnace as can be built without the use of iron.

(b) As a result of the rapid and effective carbonisation brought about by means of the sand, the time needed for carbonisation to become complete will be considerably shorter than has been the case hitherto. The throughput of a plant unit per unit of time will be appreciably increased, and this in turn means that for a given level of output the plant will be smaller than other more conventional types and economies will be made in construction costs.

(c) The plant needed for L.T. carbonisation is fairly small in relation to the average throughput, as can be seen from the fact that the difference between methods is as follows: for Spülgas carbonisation, approximately 1,000 cu. m. of heating gas are needed per ton of coal put through the plant, whereas, for the sand-carbonisation process, two-thirds of a ton of sand are needed per ton of coal in charge. The equipment for separating, heating and transporting the sand is simple and explosion-proof, and it is not necessary to build large bunkers with massive foundations.

(d) Continuous operation of the plant, which brings about a considerable reduction in men required to operate the plant, is particularly suitable for this process, in which the hot sand flows to the furnace simultaneously with the briquettes and is then separated from the L.T. coke.

(e) By raising or lowering the temperature of the sand, or by changing the ratio between the quantities of sand and coal, the greatest possible degree of adjustment of carbonisation conditions to suit the properties of the coal to be carbonised can be made by the simplest of means.

(f) The change over from the production of locomotive coke-briquettes, weighing about 6 kg., to the household carbonised briquettes which weigh 45 g., can be achieved by exchanging the rollers in the briquette presses, while the temperature can be changed by any of the means indicated under point (e). This is also true of the treatment of coal nuts.

(g) The production of an undiluted L.T. carbonisation gas of high calorific value has already been referred to above.

(h) Over-heating of the tar vapours cannot occur during carbonisation as long as the temperature of the sand is properly controlled and is chosen to suit the required carbonisation conditions. Since the L.T. carbonisation tar only comes into contact with the sand in a state of vapour, there is no possibility of the tar (which only becomes a liquid after being cooled down) mixing with the sand, or being absorbed by it. The dust content of the L.T. carbonisation tar is never above that of the tar obtained in H.T. carbonisation furnaces.

(i) The yield of L.T. carbonisation tar is in the region of the maximum attainable, since the heated sand brings about a perfect removal of all the tar in the coal to be carbonised, and the tar released as vapour is first deposited after cooling.

Caking together, which tends to occur when briquettes are made with pitch as a binding medium, cannot occur during the sand-carbonisation process, as the briquettes never touch one another.

Low-temperature carbonisation smelting process

This process was introduced by Weber, and Thau⁸ reports that a trial plant has been erected in the Rhineland as well as in the Ruhr district. The process operates on coal slack mixed in an exactly determined proportion with fine-grained iron ore, the mixture being pressed into the shape of large ovoids, using coal tar pitch or residuals from a hydrogenation plant as a binder. In the Rhineland these ovoids are carbonised in a vertical shaft through which hot gases are passed and, in the trial plant in the Ruhr district, they are carbonised in a revolving drum, using hot sand as a transmitter of heat. The carbonised ovoids are subsequently charged into a low-shaft furnace yielding pig iron and gas, which may be of high calorific value if oxygen is used for the blast.

The ores treated in this process are those which are difficult to smelt in blast furnaces in the ordinary way and the use of the reactive L.T. coke produced in the Weber process makes such smelting possible.

The smelting process thus combines three processes in one:⁸ L.T. carbonisation, smelting, and synthesis gas production.

The Didier process

In his survey of the present position of German carbonised briquette plants, Thau⁸ records that the Didier plants in Silesia are now in Russian hands. Georges² mentions the possibility of there being four vertical refractories at Mislowitz (Upper Silesia), designed for an initial capacity of 500,000 tonnes. The Didier vertical retort for L.T. carbonisation of nuts and ovoids is fully described by Thau.⁶ The yield of tar and gas, as well as the calorific value of the latter, is adjusted by introducing de-tarred gas to the base of the charge in externally-heated, continuously-operated vertical chambers. These ovens correspond in

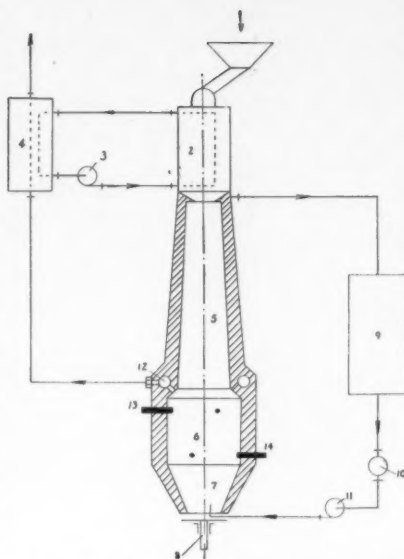


Fig. 6. Section through Norsk Hydro plant for briquetting coal using concentrated sulphite waste liquor as binder.

most respects to the Woodall-Duckham continuously-operated vertical retort, the construction of which served as a basis for these ovens, although the heating arrangement was altered completely to adapt it to L.T. carbonisation.

Coals of the most varied kind and from widely differing sources have been carbonised at low temperature in the experimental plant at the Didier works. When the plant was operating without interruption, a fuel oil suitable for marine use could be obtained.

The Otto process

The Otto L.T. carbonisation retort has been developed from the Otto vertical chamber retort for gas works.⁷ This vertical retort was equipped with twin vertical flues, and this form of construction has been retained for the L.T. carbonisation retort. The principle advantage of the twin flues lies in the fact that they made it possible with ease and certainty to obtain and retain the desired temperature in all sections of the retort chamber. Using such a retort it is thus possible to obtain the maximum yield of tar, and also coke incorporating all the most desirable qualities. The retort has been specially designed to handle non-caking coal. Extensive tests on this retort were carried out from 1938 to 1944 in the experimental coking plant of D. C. Otto & Co. The retort had a capacity of 4 tonnes day, and various types of briquettes were treated, such as those manufactured according to Weber's briquette process applied to lean coal. Generally speaking, it was found that, with correct adjustment, a L.T. coke suitable for generators was obtained, and dust-free L.T. tar resulted.

These trials finally led to the placing of a contract for a large L.T. carbonisation

plant with an annual capacity of 1 million tonnes, which was to be erected in Upper Silesia (Poland), but the outcome of the war prevented the carrying out of this project.

L.T. carbonisation of small coking coals can also be undertaken in a retort of this description, subject to certain alterations in the process, which becomes semi-continuous, similar to that met with in gas works, employing cooling chamber retorts.

Electrical carbonisation

While it has been reported that Norway has no L.T. briquette carbonisation plants at present, it is well to mention some experimental work carried out by Norsk Hydro-Electrisk Kvaelfabrikfabrikskab, Oslo, on a new electrical process for carbonising non-caking bituminous coal to make coke suitable for domestic smokeless fuel which is described by Jensen.^{20, 21}

Since underground temperatures in Spitsbergen mines are $-2^{\circ}\text{C}.$, the coals are frozen and disintegrate completely on thawing out, so that they are not very suitable with ordinary methods of firing. The ash also has a detrimental effect on acid-type brick, due to its low fusing point and alkaline reaction. The coals are unsuitable for coke manufacture in the usual type of coke ovens. The coke is highly porous, of low mechanical strength and disintegrates badly during transport and storage.

In order to use the coal to the extent justified by the large reserves, new methods must be applied and, if possible, tied up with further utilisation of the country's large water-power resources. With this object in view, Norsk Hydro, in co-operation with the Norwegian Government, started work during the late war on a new electrical process for the manufacture of high-quality coke from Spitsbergen coals. The work has now progressed to the stage where an industrial plant can be built.

Norsk Hydro process

The coal is crushed and then briquetted. Two methods of briquetting have been tried, both with good results. The first method consists of pulverising the coal, followed by high-pressure briquetting (2,500 kg./sq.cm.) without use of any binder, in a ring-roll press. The method produces strong briquettes which can stand storage under water.

The second method (Fig. 6) uses concentrated sulphite waste liquor as binder. In this case it is not necessary to crush the coal so finely as in the first method. Briquetting is at 100 to 200 kg./sq.cm. in a press of similar construction.

The briquettes are then pre-heated to 150 to 200°C. By-products of the coking process, of course, are coal tar and gas.

A charge of pre-heated coal briquettes enters the top of a vertical shaft and descends at an even rate in counter-current with gas at 1,000°C. The briquettes are

thus evenly heated. At the same time the gas is cooled at about 200°C.

At the lower end of the shaft is an electric furnace of a somewhat greater cross-section. This furnace contains two sets of three-phase electrodes. The carbonised briquettes, being now conductive, form the resistor element which provides the heat for the process. The lower end of the furnace has a conical extension through which the coke briquettes are discharged as a finished product.

The hot gases, in ascending the shaft section, acquire an admixture of tar and coke gases and pass from the top of the shaft through a Cottrell tar remover, thence through a cooler for oil separation. With a temperature of 50 to 60°C. and saturated with steam, the gas then re-enters the bottom of the electric furnace through its conical extension where it cools the coke briquettes and becomes pre-heated. In passing through the electric furnace section, the gas temperature is raised to about 1,000°C. At the same time a reaction takes place between its hydrocarbons and the steam, forming carbon monoxide and hydrogen. Part of the heated gas is used for carbonisation of a fresh charge of coal briquettes, while the remainder is piped off to be used for synthesis.

One short ton (907 kg.) of Longyear coal yields 1,250 to 1,300 lb. of coke briquettes, 20 to 25 gal. of L.T. tar of high phenol content and about 24,000 cu. ft. of gas of composition: approximately 70% H₂, 27% CO and 3% CO₂ + CH₄ + N₂. Power consumption is about 40 kwh./1,000 cu.ft. of produced gas.

To get a gas mixture suitable for synthesis, common water-gas can be added. The best procedure is to separate the raw coal into two products, one to give low-ash coke (about 4% ash) and another to give high-ash coke (about 30% ash). The latter product can then be gasified by steam in an electric furnace of the same construction as above, but without the vertical shaft.

If the gas mixture is to be used for synthesis of gasoline or diesel fuels, e.g. by the *Hydrocol* process, a plant capable of converting, say, 1½ million short tons of Spitsbergen coals yearly, will give approximately 700,000 tons of low-ash coke briquettes, 750,000 barrels of L.T. tar and 2 million barrels of gasoline + diesel fuel. Approximate power required is 3 million kw.

If synthesis gas is not wanted, an alternative gas fuel of, say, 500 B.Th.U./1,000 cu. ft., can be made by disconnecting one set of electrodes with a corresponding decrease in power load. The resulting gas consists mainly of CH₄, H₂ and CO, with no heavy hydrocarbons. Power consumption will in this case decrease to about 120 to 150 kwh./ton of coal for larger furnaces. One ton of Spitsbergen coal will then produce about 1,350 lb. of coke briquettes, 20 to 25 gal. of L.T. tar and 10,000 to

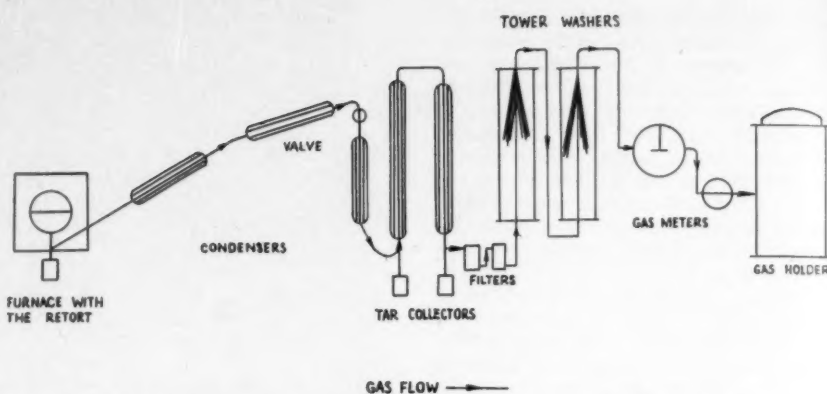


Fig. 7. Semi-industrial experimental plant for briquetting Bellampalli fines.

11,000 cu. ft. of gas of 500 B.Th.U./1,000 cu. ft.

The next plant to be built is expected to have a daily output of about 25 tons of coal briquettes. For a furnace of 150 tons daily input capacity, electrode voltage will not exceed 150 v. The resulting coke briquettes will have the properties of H.T. coke with 1 to 2% volatile matter and a compressive strength of up to 500 kg./sq.cm. Chemically they will be highly reactive, at least as good as L.T. coke.

Since the United Nations' report in 1949²⁰ the heat exchanger has been cut out and the preheating and drying of the coal is now effected by means of producer gas generated from coke breeze.

It seems doubtful whether electrical carbonisation will ever be used in countries that depend mainly on coal or other vegetable fuels for heat and power.

Laboratory and semi-industrial briquetting and L.T. carbonisation of Indian coal

Iyengar²² describes a self-supporting process for briquetting non-caking Bellampalli coal, based on the Hodsman process. The Hodsman process essentially comprises increasing the viscosities of L.T. tars by treatment with lime. The briquettes obtained are subjected to L.T. carbonisation. The tar recovered is used to briquette further lots of fresh coal, and the carbonised briquettes are used in the smelting of iron ores in the Tysland Hole electric furnace.

The lime-tar reaction

Normal tars behave as Newtonian fluids, their viscosities being independent of the rate of shear. However, by treating a vertical retort tar with lime and water at elevated temperatures, combination of the acidic constituent with lime takes place, resulting in an enormous increase in viscosity. The products no longer behave as Newtonian fluids, yet acquire a pronounced rigidity requiring the application of an appreciable force to cause movement.

Not all tars are equally susceptible to lime treatment. Tars essentially of paraffinoid or non-aromatic character, like vertical retort tar or L.T. tar, respond

most readily. One of the remarkable properties of the lime-tar reaction is the setting to 'cheese' of the products of reaction on allowing them to stand undisturbed. This 'cheese' is less susceptible to temperature fluctuations than pitch or other similar material.

The Bellampalli tar used in these experiments was obtained by distilling Bellampalli coal in a thermic carbonisation plant. The temperature in the retort was maintained between 600 and 650°C. at the time of charging. On allowing the Bellampalli tar to react with lime at 70°C., the viscosity of the tar increased from 10 sec. B.R.T.A. to over 600 sec. B.R.T.A. at 30°C. in 2 hr.

Laboratory trials of lime-tar briquetting of Bellampalli fines

Coal was first crushed to below ½ in. in a jaw crusher and then in a roller press. About 400 g. of crushed coal was taken, and to it were added about 2 to 10 g. of lime and 40 to 60 g. of tar. As the coal and tar both contained sufficient moisture, no additional water was used. Mixing was done in a Hobart mixer. Briquettes were obtained by pressing suitable quantities of the mix in a laboratory hand-operated hydraulic press using cylindrical moulds. The pressure used was about 2,000 p.s.i. The briquettes thus obtained continued to set by chemical reaction. The strength of the briquettes was determined periodically by measuring their crushing load in a Slater's compression-testing machine. The briquettes were regularly carbonised in a gas-fired laboratory furnace at 600°C. and the carbonised briquettes were tested for their strength.

Results

(1) The lime-tar reaction provides a suitable binder for briquetting.

(2) It is advantageous to carry the lime-tar reaction within the body structure of the briquettes rather than to allow it to proceed externally and then introduce it into the mix.

(3) Bellampalli tar is more reactive to lime treatment than H.T. tars. However, this tar seems to have one disadvantage, viz. the briquettes prepared with this tar

increase in their strength on storage only up to a point and then gradually weaken. This phenomena is more pronounced in the case of briquettes prepared with quicklime than with slaked lime. By suitably controlling quality and quantity of slaked lime it might be possible to minimise the weakening of the briquettes.

(4) Best results were obtained with briquettes having the composition:

Coal	..	..	..	500
Tar	..	..	..	60
Slaked lime	..	..	..	4.5

(5) The carbonisation of the briquettes at 600°C. indicated that not all tar is recovered from the briquettes. This is probably due to the tar acids in the tar reacting with lime and getting 'fixed.' The percentage of tar that gets fixed depends on the period of storage prior to carbonisation and on the mode of carbonisation. The best results were obtained when briquettes were allowed to stand over-night at room temperature and then carbonised at 600°C. for 1 hr. The tar recovered is also reactive to lime treatment and can be used to briquette a fresh lot of fines.

Semi-industrial-scale experiments

About 30 lb. of coal crushed to 2 in. were carbonised in a horizontal gas-fired thermic plant at 600 to 650°C. for about 2½ hr. (Fig. 7). The tar obtained was mixed with Bellampalli fines and slaked lime in suitable proportions and briquetted in a hammer mould. The briquettes were allowed to stand overnight and then carbonised at 600 to 650°C. for 2½ hr. in the thermic plant. The residue was dry quenched. The tar recovered was re-used to briquette fresh lots of fines under similar conditions and the process was repeated to three generations.

The reactivity of the tar to lime treatment decreases with each distillation, whilst the moisture, ash, volatile matter and the reactivity of the carbonised briquettes increase after each carbonisation.

One of the chief uses of the briquettes can be in the smelting of iron ores in the Tysland-Hole electric furnace. They were unsuitable for blast-furnace operations.

The thermic plant was constructed of an alloy of mainly nickel, chromium and iron, with traces of tungsten, manganese and silicon; the retort was gas-heated with six burners. In the normal carbonisation practice, the charge was heated from the cold; and hence took a longer time for carbonisation, whereas in the experiments described, the retort was already heated to 600°C. and then charged.

Since reactivity of the tar decreased after each distillation, after four or five operations the tar has to be replenished with fresh tar.

Iyengar²³ also records similar work which he carried out on Tandur coal and for which he was awarded a Doctorate of

Leeds University. The same carbonising plant was used. These briquettes on L.T. carbonisation were likewise suitable for the reduction of iron ore in the electric smelting process, and this conclusion has been corroborated by Messrs. Elektrokemisk A/S., Oslo.

Conclusions

The carbonisation of coal briquettes to yield smokeless fuel, tar and gas is of world-wide interest. Besides being a means for using the increasingly large proportion of fine coal produced by mechanical mining methods, the process can be applied to low-rank coals, and is complementary to H.T. coke manufacture inasmuch as non-coking coals can be employed.

The practice of burning raw coal on domestic grates is acknowledged to be wasteful and a source of dangerous atmospheric pollution. Smokeless fuel possesses neither of these drawbacks; in addition, useful by-products can be recovered during its manufacture.

The economic stability of a country largely depends upon the efficiency with which it uses its indigenous resources and, as the demand for smokeless fuel increases, so the carbonisation of briquetted coal would appear to be one of the most economic ways for producing such a fuel.

Summary

A number of foreign low- and medium-temperature coal briquette carbonisation plants are described and some account of experimental work is given. The *Phurnace*, Carmaux, Brennstoff-Technik, Krupp-Lurgi, Lurgi-Spülgas, Didier and Otto processes have all reached commercial stature.

Conclusions reached are:

(a) Carbonisation of coal briquettes to yield smokeless fuel, tar and gas is one of the chief ways of using the increasingly large proportion of fine coal produced by mechanical mining methods.

(b) The process can be applied to low-rank coals and is complementary to high-temperature coke manufacture, inasmuch as non-coking coals can be used.

(c) Smokeless fuel burning is gradually replacing the undesirable use of raw coal on the domestic grate.

(d) As the demand for smokeless fuel increases, so the carbonisation of briquetted coal would appear to be one of the most economic ways for producing such a fuel. Valuable by-products may be produced in the same process.

Acknowledgment

Thanks are due to the Director General of Research, National Coal Board, for permission to publish this survey.

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Recent publications

B.C.P.M.A. services. An eight-page booklet issued by the British Chemical Plant Manufacturers' Association outlines the history, organisation and services of the Association for the benefit of firms enquiring about membership. The services enumerated in the booklet range from placing before the Government and other bodies the views of members on matters affecting the chemical plant industry, to sponsoring members' applications for building licences, or assisting them to obtain passports, visas and foreign currency. The booklet also contains a list of current members.

Plastics buyers' guide. This 44-page octavo booklet, published by the British Plastics Federation, covers all the more important plastics materials produced in Great Britain. An interesting feature is that the actual cover is laminated with a thin sheet of cellulose acetate for protection. Each of the 17 sections has a note of the more important uses of the material concerned, the names and addresses of the member firms supplying it and the trade names used. All are indexed separately for easy reference. Price 2s. net.

Flexible tubes and hoses. These can be divided into four main types—composite, metallic, rubber and plastic. A new illustrated catalogue from Compoflex Co. Ltd. is divided into sections covering the various types of 'flexible.' Section A deals with gas tubing, light- and heavy-duty air hose and electrical conduit, while section B covers suction and delivery hose for petrol, oil, water, etc. The remaining four sections deal respectively with metallic flexibles, rubber hose, plastic hose, special flexibles and adhesive tapes. The leaves are contained in a loose-leaf folder so that new sections can be added as they are published.

FRACTIONAL DISTILLATION-1

Theory, new data, laboratory distillation, packed columns

By H. H. M. Jones, B.Sc., A.M.I.Chem.E.

AGAIN in the field of fractional distillation there has been a very large number of papers published in the past twelve months. Accordingly, this review will appear in two consecutive parts; the second part, to be published next month, will deal with bubble plate columns, perforated plates, wetted-wall columns, extractive and azeotropic distillation, batch distillation, industrial operation and low-temperature separation.

Theory

A greater number than usual of papers devoted to the analytical determination on fractionating columns has been noted. These relate the various lines of approach followed by investigators in the resolution of both binary and multi-component separations.

Dealing with the binary first, there is the general survey of the calculations of continuous fractionation by Zarate and Franconetti.¹ This is a convenient summary of the five classical methods of tackling the problem and sample calculations illustrating each method are given. Watson² outlines a procedure where the difficulty often encountered in drawing $x-y$ diagrams is overcome by plotting $(y-x)$ against x . The application of both finite and total reflux is discussed. In the more analytical field Hirata³ also modifies the McCabe-Thiele construction, but in this instance the simplified equation is obtained by modification of the operating line. The approach of Pohl⁴ is mathematical; he gives a series of tables resulting from the integrating of a continuous differential equation giving the liquid composition on any plate in a column for a definite separation at infinite reflux. Further tables are given to relate these values to finite reflux and other relative volatilities. An example of the use of the method for the separation of n - and iso -pentane is given. The somewhat similar argument from the particular to the general is developed by Boileau,⁵ who treats the problem of the distillation of mixtures of nitro-ethane and 2-nitro propane. Theoretical distillation curves for the McCabe-Thiele method have been drawn and it is shown how the method can be extended to other mixtures and other circumstances. The extension of the nomographic chart developed by Edgeworth-Johnstone⁶ is attempted by Narsimhan and Mere.⁷ A rigorous relation has

been derived to enable accurate calibration of the radius of the chart and so eliminate errors of earlier derivations. The geometrical construction is explained. A theoretical approach is that of Klemm,⁸ who develops a non-linear differential equation for the case of a binary mixture in an endless separating tube. This equation has been solved and the time dependence of the separation factors at the end of the tube is represented graphically for different concentrations and compared with experimental data.

In the sphere of multi-component calculation there is the short summary of van Wijk and Thijssen.⁹ Here recent theory is applied to the calculation of a practical multi-component distillation previously discussed by Jenny¹⁰ in his well-known paper. The case of ternary mixtures has not been particularly well investigated and Hausen¹¹ applies a theoretical treatment and the use of a triangular diagram to the separation of oxygen, nitrogen and argon and demonstrates graphically what has always been known in practice, the impossibility of obtaining pure oxygen from air under operating conditions in which the oxygen content of the nitrogen stream falls below 6.7%. In addition the general equation for ideal ternary mixtures is solved. Riediger¹² has written a nomograph on the computation of fractionating columns for multi-component mixtures, while L'vov¹³ has suggested that the fractionating problems with multi-component mixtures be regarded as mixtures of the binary systems, the number of these being readily computed from the possible permutation of components and the calculations based on the simultaneous processing of binary mixtures. However, no specific examples are given. Two examples of the use of the matrix operations to evolve an algebraic solution of distillation calculations is provided by Gäumann *et al.*¹⁴ and Hirayama.¹⁵ The first of these is an entirely mathematical approach and is claimed to be particularly advantageous for columns of many theoretical plates. The second expands the basic relation for multi-component rectification reported by Underwood¹⁶ and Harbert.¹⁷ A graphical method is possible for the special case of ternary systems and this is described. Murdoch and Holland^{18, 19} continued their mathematical analysis of multi-component distillation, which also follows closely on

the work of Underwood. The first of these gives equations in product form and their simplified application, while the second is specifically concerned with minimum reflux determination. Florin²⁰ has written an introductory paper on the analytical treatment of rectification, in which he considers fundamental thermodynamic relationships concerning vapour pressures and relates this to the volume distilled in an analytical distillation. The use of electrical analogues for the solution of distillation problems has been extended by Wilson²¹ and Morris.²² The absorption factor technique of distillation calculations has been revived by Ferro *et al.*²³ and McIntire *et al.*²⁴ and Pennington *et al.*²⁵ As with all the other methods noted here, all the usual simplifying assumptions are made.

A theoretical construction of the process of flash-distillation is presented by Bowman and Edmister,²⁶ from which mathematical expressions are derived and from which the composition of the products can be computed when certain easily determined variables are known. Florin²⁷ presents calculations of boiling points or vapour pressure for ideal multi-component mixtures in terms of an empirical temperature function.

In the general field of theory there have been papers by Orlicek²⁸ and Kamei and Takamatsu²⁹ concerning the efficiency of rectifying columns. In the first of these a nomograph is given to enable the number of theoretical plates to be obtained readily when certain operating factors are given. In the second, mass transfer equations are solved for the change of concentration of liquid and vapour in flowing across a plate. The authors show that the effect of liquid concentration on plate efficiency can be clearly explained by their results.

Data

Physical characteristics of mixtures of liquids and their behaviour on vaporisation are being constantly investigated and apparatus for carrying out such experiments is always being improved. Ellis^{30, 31} describes a vapour/liquid equilibrium still in which recycling of the condensate does not mix directly with the equilibrium liquid and so errors in the measurement of its composition are eliminated. Data obtained in this still showed very good agreement with previous work and are

thermodynamically consistent. A different approach to the same problem is evidenced by Abelwhite *et al.*³² where a vaporiser unit employing the principle of inert gas transpiration is used in the determination of vapour/liquid equilibrium; vapour condensation by means of a solid CO₂/methyl alcohol bath is applied. Equilibrium data obtained in this way are compared favourably for acetic acid/water with those obtained by the principle of thermal distillation. Novella and Tarrasó³³ have also suggested an apparatus and technique for rapid vapour/liquid equilibrium determination and they claim that the results obtained are consistent with the theoretical Van Laar equations. A name well known in this field is that of Othmer, and he and his collaborators³⁴ have suggested a high-pressure equilibrium still made of stainless steel for special application. Comprehensive vapour-pressure data have been collected together by Dreisbach,³⁵ while Winn³⁶ presents a nomograph from which the vapour/liquid equilibrium data from hydrocarbons can be determined in terms of temperature and pressure.

There have been references to the treatment of equilibrium data and the best use to which this may be put. Sage and Reamer³⁷ described the minimum amount of data necessary for estimating phase behaviour and thermodynamic properties, while Reed and Meyers³⁸ give two graphical methods for constructing the conventional x/y diagram from multi-plate equilibrium still data. The first method involves several simultaneous samples from different plates and the second depends on an accurate calculation of at least one point on the one-plate equilibrium curve. The equations and tests for vapour/liquid equilibrium data under both isobaric and isothermal conditions are given by Hetherington.³⁹

Manipulation and estimation of equilibrium constants have received a deal of attention. Organick and Brown⁴⁰ give a method of predicting them, while Arnold⁴¹ reviews the limitations of their use in the case of hydrocarbon mixtures. Here their use, although very common, has never been completely satisfactory, as the constants should always be estimated in terms of the composition of the mixture, and errors arising from the neglect of this are greatest with compounds of low molecular weight. These errors, he shows, may be correlated in terms of a convergence composition. This point is also made by Kay and Nevens⁴² to show that the equilibrium constant of ethane when mixed with aromatic compounds differs appreciably from that when it is mixed with other paraffins and from that evaluated on the basis of fugacities, taking into account conditions of temperature and pressure. Gilliland and Sullivan⁴³ make similar deductions concerning ethylene, and Van Winkle⁴⁴ likewise notes that the errors are much smaller in the case of heavier hydrocarbons.

A method of transposing vapour pressure/temperature data for hydrocarbons obtained by batch distillation from one pressure to another is given by Lamb and Sitar,⁴⁵ who developed theoretical equations to permit the calculation of distillation curves at pressures from 1 to 760 mm.; a modified Cox chart permits straight-line interpolation and extrapolation of data.

Binary vapour/liquid equilibrium for many systems reported during the year are collected by Walsh⁴⁶ and, in addition to the systems mentioned there, Kay and Brice⁴⁷ give the equilibrium results for the system ethane/hydrogen sulphide, showing that an azeotrope is formed between them which varies with pressure. Also of interest in processing with natural gas is the system carbon dioxide/hydrogen sulphide, details of which are given by Bierlein and Kay.⁴⁸ Their results show great deviations from Raoult's law and that separation is easy at high but very difficult at low H₂S content. Hellwig and Van Winkle⁴⁹ add to the sum of knowledge of the oxidised hydrocarbon series, giving details of the systems, of ethyl alcohol with *n*-butanol, *sec*-butanol, *n*-pentanol, acetone, methyl ethyl ketone and methyl *n*-propyl ketone. Finally, Rose *et al.*⁵⁰ put forward an improved method for the use of the Gibbs-Duhem type of equation, together with vapour pressure/temperature and boiling point/composition relationships in predicting binary vapour liquid equilibrium. A trial-and-error method is used which at present has its limitations, but the advantage is that experimental error is avoided.

Laboratory distillation

The papers on this subject may roughly be divided into two categories, namely the design and improvement of apparatus and its utilisation in the resolution of specific fractionation problems.

Information on laboratory practice has been collected by Krell⁵¹ concerning the use of continuous distillation in the laboratory, and Munch⁵² adds details concerning control apparatus for such equipment. Jaulmes⁵³ makes recommendations for the better utilisation of experiments to obtain practical results.

By far the most common laboratory column is packed with some material or other and Kolling⁵⁴ evaluates much relevant data which has been published concerning such matters as column loading as a function of pressure drop for various packings and various charges, loading at reduced pressure and efficiency of various packings as functions of loading. Optimum operating range for such equipment is also given. Schultze and Stage⁵⁵ have made a thorough study of the behaviour of fractionating columns for the laboratory and give specifications for the column and drawings of the associated parts. Examples of column design are given by Romanet,⁵⁶ who goes into detail on the adiabatic operation of a distillation column and

conducts his experiments to show that greater ease of separation of components of a mixture results when heat loss is reduced to a minimum. Improved column ancillaries are: an automatic fraction collector by Varner and Bubler⁵⁷; a fractionating still head with adjustable vapour-splitting valve to give constant reflux ratio independent of reflux boil-up rate, by Payne and Perrins⁵⁸; and a magnetic drive for a spinning-band column which eliminates a gland and so enables long continuous runs at high-vacuum process, by Foster and Green.⁵⁹ Finally in this section Whear⁶⁰ describes a semi-scale distillation packed column with extensive control instruments, which was used on the distillation of alcoholic wash.

In the field of laboratory apparatus for the solution of specific problems comes the modified Oldershaw column used by Dimick and Simone⁶¹ for the distillation of essence solutions of volatile flavours. The distances between the plates and the plate perforations were increased so that aqueous solutions could be rectified without excess flooding and high-pressure drop. In the experiments the distillable flavours were concentrated at least 500-fold in a single distillation. Zuiderweg⁶² conducted experiments to compare the performance of a Vigreux column and a spinning-band column over a wide range of pressures. He found that as pressure was reduced in the first case the liquid viscosity naturally increases, but this is partly compensated for by the increased vapour rate, with the result that the total efficiency loss is only 25%, which corresponds to a total pressure reduction of 760 to 1 mm. The liquid phase accounted for only about half the total resistance at atmospheric pressure; on the other hand, the spinning-band column in which the main resistance is due to the vapour phase suffered a loss of efficiency of 70% when the pressure was reduced from 760 to 10 mm.

The effect of mechanical agitation of the column on the fractionation of carbon-tetrachloride/benzene was carried out by Garcia,⁶³ who reported that the increase in efficiency was not sufficient to justify the extra complication. Among the laboratory separations reported is the work of Feldman and Orchin⁶⁴ on the separation of the α and β isomers of methyl naphthalene by azeotropic distillation, using an entrainer. Undecanol and 2-amino-3-methyl pyridine were used as the latter, and the pressure of operation adjusted so that an azeotrope was formed with one isomer but not with the other. Scott *et al.*⁶⁵ give experimental data for the separation of some methyl esters of fatty acids and showed that, with the esters of acids having successive, even numbered, carbon atoms if saturated, fractionation is easy, but it is otherwise with the esters of unsaturated acids, which require between 250 and 500 theoretical plates. Dostrovsky *et al.*⁶⁶ described improved columns which have been in use for some years for the enrichment of

heavy isotopes of oxygen in water. These columns have the equivalent of 400 to 600 theoretical plates. They now apply the theory of practical distillation to the data and make it possible to derive simultaneously the values for what they call the unit process separation factor and the effectiveness of the column for the system used. A graphical method is presented which facilitates the derivation of such information from experimental data. The effect of salt in the vapour liquid equilibrium of ethyl alcohol/water is investigated by Novella and Tarrasó,⁶⁷ who show that the addition of potassium acetate and copper chloride to certain binary mixtures greatly increases their ease of separation and may even eliminate azeotropes. This effect is not obtained if the salt is soluble only in the less volatile constituent. The Hiag process for the production of absolute alcohol by the use of a mixture of sodium and potassium acetate, of course, employs this principle. For the testing of columns of a pressure range 10 to 760 mm., Zuiderweg⁶⁰ suggests the test mixture decane and decaline be used. The system obeys Raoult's law and the vapour pressures of the constituents and vapour equilibrium measurements were checked for thermodynamic accuracy at atmospheric pressure. The mixture *n*-hexadecane and *n*-heptylbenzoate may be used in the pressure range 1 to 15 mm., but it contains an azeotrope at about 90% *n*-hexadecane which limits use for the evaluation of columns of not more than 16 to 18 theoretical plates.

Packed columns

There have been increasing investigations into columns utilising as fillings other devices than the rings or saddles, which are now seen to be deficient in certain characteristics such as high efficiency, low-pressure drop, low hold-up, etc. For instance, Hayter⁶⁸ gives data on the performance of a corrugated-wire-gauze packing and found that for the range studied the mesh size (38 to 72) has no appreciable effect on fractionation nor, seemingly, has the packed height. Further investigations were made into the characteristics of the Stedman packing by Fookson *et al.*⁷⁰ on the use of such a device at low temperatures for the distillation of hydrogen and isotopes. They found that with the 12-in. packing used the H.E.T.P. was calculated to be 1 in. at boil-up rates of between 454 to 1,190 ml./hr. Bliss *et al.*⁷¹ in their experiments to determine the effect of low pressure on packed column operation, used a packing consisting of 'bells' closed at one end and strung on wire and suspended vertically. The device was intended to give low-pressure drop. However, most results were for a Raschig-ring-packed tower and show that H.T.U. values varied inversely with the pressure and temperature raised to some power. It was stated that the few results for the new packing were comparable. A simple helical tray on a laboratory scale is sug-

gested by Shortland⁷²; an arrangement of a closely coiled spring is described and, as with other metal packings, pre-flooding increases efficiency. Complete data on the older established tower packings have been collected by Leva,⁷³ and the methods of calculation for such columns have been critically reviewed by Zuiderweg,⁷⁴ who concludes that none of them is entirely satisfactory and suggests a simplified relation for the calculation of flooding velocity and H.E.T.P. values for columns packed with Raschig rings. The features which influence the efficiency, design and operation of packed towers have also been examined by Williamson,⁷⁵ who in addition develops an expression for the optimum vapour velocity based on the vapour film being the controlling factor in mass transfer. Efficient liquid distribution is again emphasised. The relationship between the mass transfer factor and modified Reynolds number is taken up by Kaufman,⁷⁶ who extends the data of Gamson *et al.*⁷⁷ and Hobson *et al.*^{78, 79} for spherical packings. The effective area of packing was evaluated statistically and in this the experimental data of Taecker *et al.*⁸⁰ for commercial packing was used. This effective area factor may be less than the total area of the particles (in the case of Raschig rings and the like) or more than the effective area in the case of Berl saddles where increased turbulence is responsible. Equivalent particle diameters are calculated for various types of packing for use in the modified Reynolds number. Experiments by Skulman and DeGroff⁸¹ show that the effective area of 1-in. Raschig rings was greater than the wetted area. Ergun⁸² also used the Reynolds correlation between heat transfer and fluid friction with the extension made by Chilton and Colburn to cover mass transfer. He suggests that, as pressure loss through packed columns follows normal fluid-flow loss, it should be possible to correlate mass transfer and pressure drop. The published data of earlier works is analysed to confirm this.

In the field of experimentation with packed columns in order better to understand their function, Pratt⁸³ has demonstrated that there is a minimum liquid rate for which the packing is as wet as it can be, and gives an equation correlating the variables enabling this to be defined. Since this minimum liquid rate is rarely exceeded at the low liquid rates used in distillation, the necessity of considering a factor incorporating a degree of wetting into packed column calculations is important. Even so, a packed column is most efficient at or near the flooding point, and Dell and Pratt⁸⁴ have shown that a previously developed equation for liquid extraction columns is applicable with slight modifications to gas/liquid systems, though it is limited to certain sizes of packing.

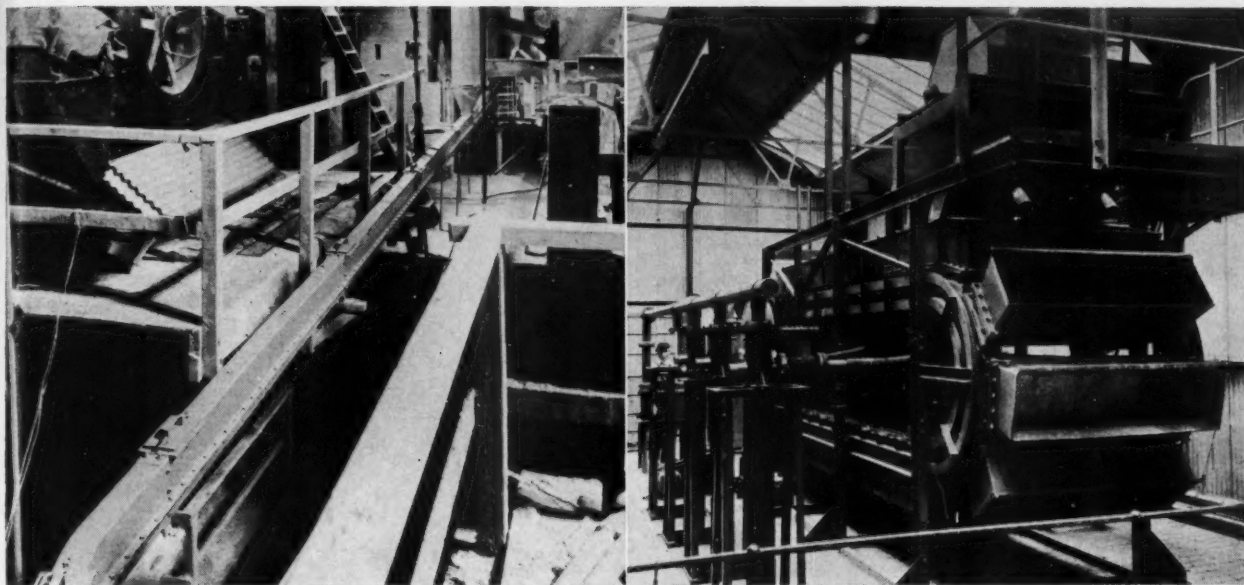
Another operational difficulty in calculating packed columns is the effect of liquid hold-up and Otake and Okada⁸⁵ give a general equation expressing hold-up

in terms of operational variables in the case of columns packed with Raschig rings and Berl saddles; they conclude that most of the previously reported data on static and operational hold-up can be correlated by the equations. A different aspect of the functioning of packed columns has been continued to be investigated by Fuchs,⁸⁶ who states that the chemical nature of the packing may be used to give a more efficient separation so that the process is actually a combination of chromatographic separation and fractionation.

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(Concluded on page 359)



Left: General view of the air-flow conveyor which carries ground phosphate to the phosphoric acid plant. Right: The Nordengren tray belt filter—the first of its kind to be installed in Britain.

New Phosphoric Acid Plant

Part of £100,000 Development Plan at British Fertiliser Factory

DURING, and especially after, the war there was an increasing demand for a more concentrated form of phosphate fertilisers, including triple superphosphate containing 45 to 50% P_2O_5 . This popularity made it essential for the superphosphate manufacturers to study the question of the manufacture of triple superphosphate and the necessity for acquiring new plant.

The Farmers' Co. Ltd., Barton-on-Humber, Lincolnshire, under the direction of Mr. R. B. Risk, had been keeping a close watch on the position since 1944 and the natural outcome of this was that the company early in 1950 decided to go ahead on a £100,000 modernisation and development plan which included a new phosphoric acid plant as well as alterations to their existing superphosphate plant, and an extension of their sulphuric acid plant.

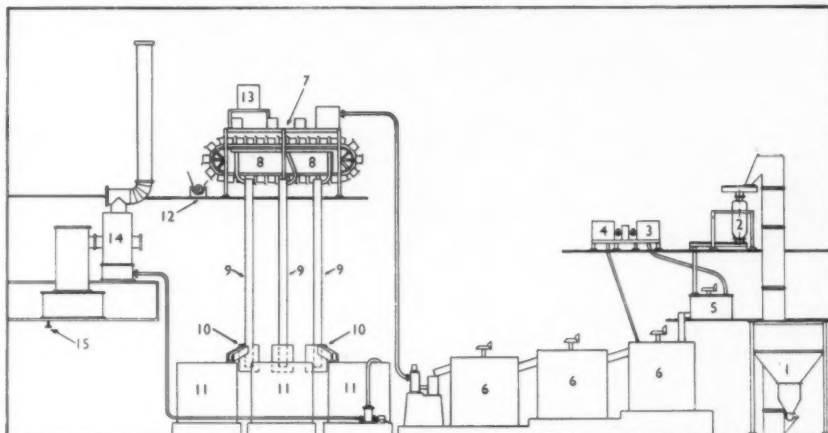
The design and supply of a phosphoric acid plant was eventually entrusted to the Sturtevant Engineering Co. Ltd., London, who had recently concluded an agreement with Mr. Sven Nordengren, of Sweden, one of the leading international authorities on phosphoric acid manufacture.

This plant, which contains several novel features, has recently been completed and tested, and is expected to become a model for future installations by other fertiliser manufacturers.

The process

The process is based on the Nordengren dihydrate process and is briefly as follows.

The phosphate is ground to a fineness of



- | | | |
|-------------------------|---------------------|------------------------------|
| 1. Phosphate bin | 6. Digesters | 12. Gypsum conveyor |
| 2. Weighing apparatus | 7. Tray belt filter | 13. Wash liquid tank |
| 3. Phosphoric acid tank | 8. Suction box | 14. Acid concentration plant |
| 4. Sulphuric acid tank | 9. Barometric tubes | 15. Product outlet |
| 5. Mixer | 10. Drain traps | |
| | 11. Filtrate tanks | |

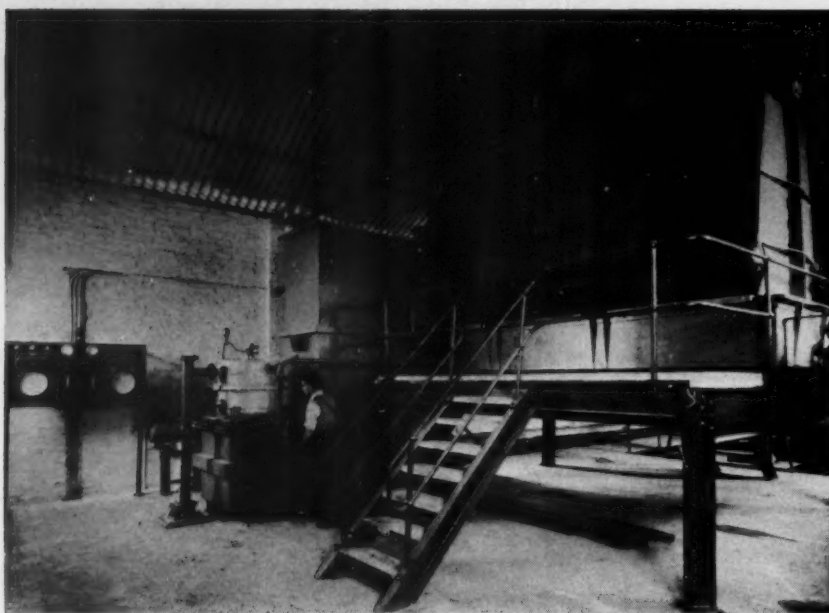
Arrangement of phosphoric acid plant.

between 85 to 95% through 100 mesh and is first mixed with a large amount of weak phosphoric acid in a pre-mixing stage. This slurry is thereafter mixed with sulphuric acid of a strength between 65 and 75%. During the reaction the temperature is controlled by recirculating the sludge. Stable dihydrate crystals are formed under a temperature of 80°C., and for the lower grade of phosphates the temperature margin is very small. Thus close temperature control is of the utmost importance. After

a reaction period of from 8 to 10 hr., the sludge is pumped to an acid filter where the phosphoric acid is removed from the gypsum crystals, part of the acid going as product and part being returned to the system as circulating phosphoric acid. The dried gypsum is diluted and pumped or carried to a disposal dump.

The plant

The phosphoric acid plant is housed partly in an existing building, which has



The Swindin submerged combustion evaporator used for concentration of phosphoric acid.

been extensively modified, and partly in a new specially designed building, which also houses the extension to the sulphuric acid plant. The nominal capacity is 10 tons of P_2O_5 per 24 hr., and the nominal output of phosphoric acid concentrated to 50% P_2O_5 will, therefore, be 20 tons/day. However, it is anticipated that the actual output will prove to be in the region of 25 to 30 tons/day of concentrated acid.

The phosphate is ground in an existing Sturtevant ring-roll mill and transported some 140 ft. to a storage hopper in the new acid plant by an air-flow conveyor. This conveyor is arranged so that, if required, it can discharge ground phosphate to two hoppers in the superphosphate plant, and has been fitted with an alternative inlet from a second grinding mill to allow for experimentation with varying degrees of phosphate fineness. It is interesting to note that the power consumption of this long conveyor is under 1 b.h.p.

The ground phosphate is fed from the storage hopper to an automatic weigher discharging on to a screw feeder which regulates the flow of phosphate to the mixer. This is driven by a variable-speed motor fitted with a tachometer generator so that any slight variations in the load to the weigher, or of the electric supply, are immediately corrected by means of an electronic device. Adjacent to the weigher on the top floor of the digester section are also situated the two acid measuring tanks which are specially designed rotary feeders, each having a variable-speed drive. The pre-mixer has a lead-lined mild-steel vessel with stainless-steel agitators.

The main reaction takes place in three digesters comprising lead-lined timber tanks with heavy lead-covered agitators and driving gear. The lead lining of this

and other items of the plant has been carried out by the Farmers' Co. with their own men and equipment.

The first digester has been fitted with thermostatically-controlled immersion heaters to maintain a temperature of 60 to 70°C. when the plant is shut down for cleaning and maintenance.

Although it is intended to use high-grade Morocco phosphate, it may be necessary to use lower-grade phosphate, when the formation of froth in the early reaction stage can be quite troublesome. To combat this, a mechanical anti-frothing device has been included which effectively beats the froth to a liquid sludge before returning it to the first digester.

The main sludge pump is fitted with an overflow to a stand-by pump, and these as well as all other primary pumps are of British LaBour manufacture in nickel alloy.

The acid filter, which was made in Sweden during a home shortage of stainless steel, is a Nordengren tray belt filter of an entirely new design and is the first of its kind to be installed in Britain. This type of filter is a great improvement over its predecessor, the Landskrona filter. It consists of a series of filter boxes connected up to form a conveyor belt and fitted with stainless-steel perforated plates on which are fixed synthetic filter cloth of a new and improved type. The bottom plates of the filter boxes are connected by a set of rubber pipes to a rubber rope which slides over a suction box. This is partitioned off according to the filtrate fractions required, and each compartment is connected to a barometric tube which is under 80% vacuum. The bottom ends of the barometric tubes are sealed off in hydraulic closures. The sludge is fed on to the

filter boxes by means of a rotary bucket feeder, the speed of which is synchronised with the speed of the belt. As the filled filter boxes come under suction from the first suction compartment, the acid is drained off through the tube and overflows from the hydraulic closure into a filtrate tank. As the belt enters the next compartment, wash liquid from a following filtrate fraction is fed on to the trays from an adjustable wash box overhead, the last wash liquid being pure water, and spillage water from the filter drain. Three or four filtrate fractions are taken from the acid filter. The first filtrate will contain approximately 30% P_2O_5 , dependent upon the grade of phosphate used, and is pumped up to a feed tank connected to the evaporator. The second filtrate, containing 18% P_2O_5 , is returned to the process as circulating phosphoric acid in the pre-mixing stage. The third and fourth filtrates, containing from 5 to 7% P_2O_5 , are returned to the filter as wash liquid.

Vacuum is provided by a Sturtevant rotary exhaustor, and a series of lead-lined sealed vessels in the vacuum line ensures that any acid fumes are trapped and neutralised.

The dry gypsum cake falls from the end of the filter into a paddle mixer, where it is diluted with water and gravitates into a gypsum storage tank fitted with a mechanical agitator. Once every hour the gypsum is pumped to a disposal dump approximately $\frac{1}{2}$ mile away, and the pipeline flushed with water.



Section of the phosphoric acid plant showing the digester machinery.

The evaporator, which was supplied by Nordac Ltd., includes a pre-evaporator where the liquid is preheated by means of the waste gases from the main evaporator. The liquid passes from the pre-evaporator through a control valve to the main evaporator. This is a heavy rubber-lined steel tank with an internal lining of acid-proof refractory bricks. The main evaporator is fitted with a Swindin submerged combustion chamber using an oil burner which was specially developed for this plant. The combustion flame is released beneath the surface of the liquid, giving an almost complete heat transfer. The pulsations in the liquid are utilised to create a circulation within the evaporator chamber. The concentrated acid overflows through an overflow box and is gravitated into a storage tank from which the acid is pumped to the phosphate acidulating plant. Fumes from the mixer,

digesters and the evaporator are removed through a partly lead-lined timber ducting and are drawn through two wash towers arranged in series.

It is worth noting that this plant has been designed for conversion to the Nordengren anhydrite process, which is the latest and most up to date of the wet processes and promises to be the most efficient one for phosphoric acid manufacture. This process, however, is still only in the experimental stage, although full-scale plants are now being built on the Continent. The main feature of this type of plant is the production of phosphoric acid containing 45% P_2O_5 without the need for concentration.

The new plant at Barton-on-Humber promises to be a most economical venture because of the relatively low capital expenditure, the simplicity of the process and the low operating costs.

Correspondence

Carbon and Graphite Chemical Plant

DEAR SIR,—I was very interested to read the paper on this subject in your October issue. I was called upon to open the discussion on this paper when it was given at the Chemical Engineering Conference and I think you might be interested in publishing my remarks as enclosed.

R. WILSON,

British Acheson Electrodes, Ltd.
Sheffield.

We are pleased to give space to Mr. Wilson's comments, as follows:

This field is extremely wide and because of the time limitation the subject has had to be condensed. Mention has been made of most, though not all, types of impervious graphite chemical equipment, but, in my opinion the authors, in condensing the subject, have failed to give a truly representative picture.

I intend, therefore, to limit my remarks to modifying certain facts and figures not representative of the graphite industry generally, and to enlarge upon some of the equipment now in use and in full-scale production in this country, which the authors have either omitted or mentioned only briefly.

In discussing properties* the authors have stated that the figure for electrical resistivity normally adopted for the design of electrodes and anodes is 0.0007/ohm/cu. in. This is incorrect—the figure adopted is a maximum of 0.00047 and normally running from 0.00038 to 0.0004, about half the figure quoted by the authors. If 0.00047 was exceeded there would be an extremely loud outcry from the steel and chemical industries.

In Table I, I noted that the thermal

*C.P.E., October, p. 315.

conductivity for Delanium graphite is given as 40 B.Th.U./sq. ft./hr./°F./ft. Later, it is stated that carbon graphitised at 2600°C. has a thermal conductivity of 60 to 75 B.Th.U./sq. ft./hr./°F./ft. and carbon graphitised at 3000°C. a conductivity of 75 to 80 B.Th.U./sq. ft./hr./°F./ft. While I do not wish to comment on the graphitising temperature used, I would say that the bulk of the graphite made today has a thermal conductivity of around 75 B.Th.U./sq. ft./hr./°F./ft. and that impervious graphite heat transfer equipment is available with this same high thermal conductivity figure.

I entirely agree with the authors' statement that the compressive strength of graphite far exceeds the tensile strength. They do not, however, quote any figures for tensile strength and I feel that I ought to mention that impervious graphite is available with tensile strengths ranging from 2,000 to 2,600 p.s.i. which, in my opinion, does not limit the design of equipment so much as the authors seem to imply. However, they are substantially correct and it is noted that the trend in design over the last few years has been to bear this fact in mind and to obviate as far as possible such methods as graphite flanges being pulled up against rigid steel equipment. Where this is not practicable, however, such applications as flexible joints are used successfully to avoid over-stressing the graphite.

The development of the impervious graphite tube bundle has been fairly well covered in the paper, but it is interesting to note that single units of this design have now been developed and are available from domestic sources to give up to 600 sq. ft.

effective outside area, and naturally single units of any size within this range can be made. The limiting of size is governed by the diameter of the largest tube plate which can be made and these are now available up to 30 in. diameter.

Only very brief mention was made of the direct immersion type of heaters. These are particularly useful for heating liquors in open vats, such as one used mostly in the metal processing industry, where the circulation of corrosive liquors involving pipe lines, pumps and valves, etc., is undesirable. Plate type heaters have been developed which are robust, are manufactured from a solid block and have no cemented joints below the liquid level. Such units are available with a surface area of up to 15 sq. ft. and if cemented joints are used, single units up to 60 sq. ft. can be made.

A new and interesting immersion unit now under development is the basket-type heater; this consists of a tube bundle with both shell, tubes and tube plates made of impervious graphite. Steam is passed through the shell outside the tubes. The tube plates are open to the liquor in the tank and comparatively high fluid velocities are obtained in the tubes by natural thermal convection. Overall co-efficients above 200 are expected against 80/100 for normal immersion equipment.

Carbon pumps have been mentioned, but I would like to enlarge a little on this item of equipment. As the authors have stated, carbon pumps have been in successful operation for many years and over that period a great deal of experience has been gained. The most recent types, therefore, embody the sum total of this experience with regard to such features as robustness and gland design, and under the normal handling expected in the average chemical works, they are no more liable to damage than the conventional types. A wide range of sizes has been developed to give capacities from 15-400 gal./min., but so far they are all of the centrifugal type.

One cannot leave pumps without mentioning their ancillary equivalent, such as pipes, pipe fittings and valves. A wide and standardised range of these items is now available in impervious graphite.

Finally, I would like to mention absorption equipment. The authors have given us a detailed description of an HCl absorption plant based on the cubic block. Impervious graphite, however, readily lends itself to other types, and falling film absorbers using graphite tubes have been successfully operating for many years throughout the world, including Great Britain.

In conclusion, may I say that I naturally feel that a paper with such a title should encompass as wide a field as possible, although even with my contribution I am conscious of many omissions. I have, however, found the paper extremely interesting and offer my personal congratulations to the authors.

Two Recent Reports have Lessons for the Chemical Engineer

DISCUSSION AT LONDON CONFERENCE ON CHEMICAL ENGINEERING

Implications of the O.E.E.C. Report

By Sir Harold Hartley

I HAVE been asked to open the discussion on two reports which were issued recently on chemical industry in the United States. The first, with the misleading title of *Chemical Apparatus in the U.S.A.*, was written by a Technical Assistance Mission consisting of European experts with only one British member, organised by the Organisation for European Economic Co-operation; the second with the title *Heavy Chemicals* was written by a Productivity Team representing the British heavy chemical industry working under the aegis of the Anglo-American Council on Productivity.

Both enquiries produced most valuable reports which are complementary to one another and should be read together. My remarks will be directed mainly to the O.E.E.C. report, as Mr. Grange Moore, the leader of the British Productivity Team, is to speak after me.

The primary object of the O.E.E.C. mission was to investigate how it was that the American chemical industry, starting from a small beginning, had captured, in less than 40 years, 36% of the world's market. You will remember that Sir Henry Tizard has pointed out that during this period the share of the British chemical industry had not increased. The first part of the O.E.E.C. report contains a striking analysis of the factors that have contributed to the rapid expansion and strength of the American industry, including its organisation and training. The second part deals with certain technical advances in the industry in recent years with forecasts of future trends.

The objective of the British team was to study the various factors affecting the productivity of the American heavy chemical industry other than 'secret technical process know-how,' so that this report deals much more with the general problems of technical and commercial management and the reasons why productivity in the heavy chemical industry in the United States is roughly 2½ times greater per employee than in Britain. But although these two reports cover different ground, their findings confirm one another in certain basic issues.

The title of the O.E.E.C. report is quite misleading and may well limit its circulation. It should, of course, be 'Chemical Engineering in the United States,' as chemical engineering is emphasised from the first page to the last as the fundamental

A discussion on British chemical engineering in the light of two recently published reports was held during the Chemical Engineering Conference organised by the Institution of Chemical Engineers and the Chemical Engineering Group, S.C.I. The reports are 'Chemical Apparatus in the U.S.A.', published by the O.E.E.C., and 'Heavy Chemicals,' published by the Anglo-American Council on Productivity. The discussion was opened by Sir Harold Hartley, past-president of the Institution, and it was continued by Mr. Grange Moore, leader of the British Productivity Team which toured the U.S. to gather material for the heavy chemicals report. These two addresses appear below.

strength of the American industry. But much as America has done to create the modern chemical engineer, readers would get an entirely wrong impression of the status of chemical engineering in the U.K. from two sentences in the report: 'The profession of chemical engineering was first defined in Europe in the second half of the last century and a short-lived society of chemical engineers was established in London in 1880 . . . Very few, if any, of the European schools of chemical engineering can at present fulfil all the requirements of the American accrediting committees.' Our Institution of Chemical Engineers, the accrediting body in this country, has a membership of 2,900. Its requirements are practically identical with those of the American Institute, and are satisfied, as a whole or in part, by the courses at seven universities and a number of technical colleges in this country. It is true, as both reports point out, that we need far more chemical engineers, but to avoid any misunderstanding I wish to emphasise at the outset that it is quantity rather than quality that we are lacking and we have to face the danger that some of our small output are receiving tempting offers to cross the Atlantic.

Let me now take you quickly through the main points raised in the O.E.E.C. report and their implications so far as this country is concerned.

The chemical engineer

The main conclusion of the O.E.E.C. mission is that the leading position in the chemical industry which the United States has now acquired is due largely to the rapid development of the profession of chemical engineering and its recognition by Government, by industry and in the universities.

The report lays emphasis on the fact that the chemical engineer is a new type of engineer whose field is the scientific study of the transfers of mass and energy which accompany the chemical and physical changes involved in many industrial processes. That the field is clearly defined is shown by the general similarity of the subjects of the courses in Britain and in the United States. The training of the chemical engineer demands a separate course which, by its nature, must be part of the school of engineering, and not of chemistry. The older courses in applied chemistry which deal with the details of operation have been replaced in the U.S.A. by courses in chemical engineering which deal with the underlying fundamental physical and chemical principles of process and equipment design.

The report points out how the efficiency of American industry is dependent largely on specialisation. In chemical engineering a sharp division is drawn between process design and equipment design. Process design involves the collection of data from the literature, from laboratory experiments or pilot plants on which are based the calculations leading up to the flow-sheet and to decisions as to the sizes of the various plant units and the optimum conditions of operation. Equipment design is the next stage and is concerned with the mechanical details of the construction involving specialists in different branches, including instrumentation. For each project, a chemical engineer occupies a key position as the co-ordinator of the work of the various specialists involved in it and to ensure that they all work to the contract time schedule.

The following sentences indicate the general impression formed by the mission from what they saw of chemical engineering:

'The European chemical industry can point to many highly important developments in recent times too, but practically all these are achievements in the field of chemistry rather than chemical engineering. The old European tradition of relying entirely on the combination of the industrial chemist and the mechanical engineer seems outmoded and has now become a vested interest tending to stifle chemical engineering progress in Europe. This statement is borne out by the fact that practically all important new developments in chemical engineering, such as the fluidising technique, extractive distillation, hyper-sorption and the centrifugal extractor, have been evolved in America, although most of them were foreshadowed in Europe. It is also highly significant that practically all the important correlations constituting the working tools of the chemical engineer have been established in America.

'In the United States chemical engineering became a necessity in the petroleum industry, where the skill of the chemist and the mechanical engineer alone proved insufficient to solve the extremely difficult technical problems arising from the vast and rapid expansion of the industry.'

I am sure you will all agree that the primary reason for the relatively slow development of chemical engineering in this country was the absence, until recently, of an oil refining industry, but happily that position has now changed.

The statistics given on p. 34 of the O.E.E.C. report show the wide range of industries in which chemical engineers are being employed in America. The reason is that so many industrial processes outside the chemical industry now make use of many of the modern chemical engineering techniques, e.g. for heat exchange, drying, mixing, separation and extraction, purification, instrumentation and temperature and pressure control.

The exhibits of the Chemical Engineering Plant Exhibition at Olympia show the wide applications which the plant is finding in almost every industry, for instance in the processing of raw material, the processing of food, the fermentation industry, the metallurgical industries and the production of nuclear power.

Chemical engineering constructional firms

The mission visited a number of the large chemical engineering construction firms that are equipped to handle the development of a new process from the laboratory stage to the erection of the commercial plant. On the basis of pilot-plant work carried out by the customer or themselves, they design the plant and make an economic estimate of the project. In a few cases they fabricate parts of the plant themselves, but usually the fabrication is left to specialist sub-contractors. These construction firms hold large contracts abroad and have branch offices in Europe.

The report says that in Europe there are

a number of chemical engineering contractors working on a considerable scale and specialising on various types of equipment, but that owing to the 'know-how' of modern oil refining in the United States most of the design and construction of oil refineries is still done by American firms. Taking a broad view of the position in this country, there can be no doubt that our weakness lies in the absence of firms with the wide experience and large resources of the construction firms across the Atlantic. The skill and initiative of our specialist firms is demonstrated admirably in the present exhibition; what is badly needed is some pooling of their resources to strengthen our competitive position in the world's markets for the chemical engineering plant that is playing a larger and larger part in industrial processes.

In discussing the organisation of these American firms, the report comments again on the importance of specialisation and on the key position of the 'job engineer.' The work of the contractors is facilitated by the pooling of information among the oil companies, while secrecy as regards processes in the chemical industry tends to restrict the contractor's activities.

Research

In the section dealing with pilot plants, stress is laid on the modern tendency to reduce such work as a result of the information gained by studies in applied chemical kinetics, emphasising the importance of such research in the chemical engineering schools in this country and by the research organisation recommended in the Cremer report.

Standardisation

Standardisation, both technical and managerial, i.e. of dimensions, materials, equipment and practices, has contributed greatly to the efficiency and productivity of American industry and, in the opinion of the mission, has been applied to a much greater extent in the United States than in Europe. The importance of standardisation was emphasised also by our own productivity team and the economies resulting from the use of standardised materials and equipment.

Process instrumentation

The mission was impressed by the high level of instrumentation and automatic control of processes in the United States, which they regard as vital to the high productivity of the industry. The general level is considerably higher than in Europe. They draw attention to the advantages of instrumentation and the urgent need to improve the position here.

Conclusions

The report then discusses the factors that have contributed to the leading position in the world which the American chemical and allied industries now hold in productivity as well as in range and volume

of output. In 1949 two-thirds of the world production of synthetic organic products were made in the United States—8 million tons out of 12 million. For this three advantages which America has enjoyed are partly responsible: her vast home market with free competition, the effects of two world wars when she was outside the theatre of operations, and her superior natural resources of oil and natural gas and of materials like sulphur and phosphate rock. But there are other reasons and, of these, the mission emphasises that a large part of the American success in industrial chemistry is due to the efficiency of her chemical engineers and of the schools in which they are trained.

Numerous examples are given to show that there is no lack of individual brilliance in Europe. DDT, *Gammexane*, polythene, antimalarials, penicillin and acetylene derivatives, azeotropic and extractive distillation, the fluidised-bed technique of the Winkler generator and molecular distillation all originated in Europe, but received their full development and commercial exploitation in the United States. This can be explained partly by America's advantages mentioned above, but the mission was impressed by the progressive attitude of the American people and their talent for developing and applying quickly the result of research to large-scale operation. There is a faith and belief in chemical engineering in America—an awareness that is lacking in Britain.

Contributing factors are the financial support given to large-scale organised research, the research in the chemical engineering schools of the universities, the American talent for organisation on a specialist basis, the extensive employment of highly-trained technicians and advanced personnel management with incentive schemes and extensive delegation of authority, the application of the production line technique to design and development work, standardisation, and to the emphasis given both by academic and industrial workers to the economic aspects of research and development.

What lessons can we draw from the O.E.E.C. report as regards this country? We should not copy America blindly, as we have to face very different conditions, but I am convinced that chemical engineering is destined to play a vital part in the industrial future of Great Britain. With the increasing demands of the ever-growing population of the world, there is increasing need to process food and also raw materials so as to use them with the utmost efficiency in our factories, a growing need for synthetics, an increasing dependence on low-grade metal ores and a need for nuclear power. In all this, chemical engineering must play a major part far transcending the scope of the chemical industry in which it was born. With the pre-eminence of the schools of physics and chemistry of this country and our intuitive gifts for engineering, the future is bright, as so

many of the new fundamental ideas have originated here.

I believe that we are now at a critical moment in our industrial history with the growing international competition from a new-born Germany, a new-born Japan and the rising countries of Asia, to mention no others. The value of the O.E.E.C. report is to emphasise three urgent needs of this country which would help us to meet this competition by new ideas and developments in the rapidly growing field of chemical engineering. We need more chemical engineers and more schools of chemical engineering in our universities and technical colleges. We need chemical

engineering construction companies with resources more nearly equal to those across the Atlantic so as to secure design and construction contracts in the world market. We need more financial support for chemical engineering research both in the universities and technical colleges, and in a specialised laboratory with support from Government and industry, as was envisaged in the Cremer report. But, above all, we need a more general recognition of the part that chemical engineering is bound to play in modern industry, otherwise we shall not secure quickly the priorities of finance and building needed for these three vital developments.

Four Points from the Productivity Report

By Mr. J. Grange Moore

AS you know, the British heavy chemical industry sent its productivity team to the U.S.A. in March last year. The team was 17 strong—management, technical specialists, shop floor and union interests were represented. In six weeks we toured heavy chemical factories situated as far south as Texas and as far west as Nevada; we saw old and new, large and small, good and not so good. Our report, published in January of this year, was unanimous. It listed no less than 20 major recommendations. We are convinced that, if these are implemented, the productive efficiency of our own heavy chemical industry, good though it may now be compared with that of some other British industries, can and will be very substantially increased.

You are probably expecting me to touch on what our report has to say about chemical engineering. Indeed, when I was preparing my notes for this short talk, I asked Dr. Hoblyn to mark those parts of the report which obviously concerned the chemical engineer most closely, and this he very kindly did. They deal with the layout, design and erection of plant, with instrumentation and automatic control, with simplification and standardisation, and with the training and employment of chemical engineers. In a word, they are precisely those parts of the report which would be read by any chemical engineer who was, as most of us are, sore pressed for time yet anxious to keep up to date with his subject.

But let us be logical. Let us deliberately put aside what can so easily, and probably has been, read. Let us consider instead four matters in the report which perhaps are more likely to be missed, although, as I shall now try to show, they concern the chemical engineer profoundly.

1. The use of cost information

We were very impressed on our tour by the realistic and practical attitude towards cost information which was so

widespread in American chemical factories. For example, both process and maintenance foremen, and indeed many of the men, knew the costs of the things under their control and governed their actions accordingly. Junior management had clear-cut instructions to get their operating costs down, and when they had succeeded they were sometimes congratulated, sometimes promoted, but still were told, 'Now get them lower.' Frequently the men running the plants were chemical engineers, and it was common to find a chemical engineer *on each shift*, perhaps with only half-a-dozen process workers under him, but he was there for the specific purpose of finding out how to get maximum production from his plant at minimum cost.

In Britain, too, many of us are content to regard cost sheets as secret documents which, provided the figures they contain are accurate to several decimal places and show no major increase which cannot readily be explained, are to be kept locked away from the prying eye of man. Indeed, I believe that some works accountants regard their task as finished when they have produced these cost sheets, not realising that a cost sheet itself is worthless and only takes on value in proportion to the use which their management at all levels makes of it.

It was very interesting to find in one American factory that a chemical engineer was employed full time by the works manager to translate the accountant's cost sheets into technical memoranda of cause and effect, and these were widely circulated and studied eagerly by the process staff as being of real assistance in the major objective of reducing costs. Those factories who were using standard costing rather than historical costing were emphatic that the change had resulted in a much closer control of their process costs, though we were surprised to find that the use of standard costing was only a little more general than it is in Britain.

You may by now be wondering—what has this close study of operating costs to do with the chemical engineer? I think that the question really answers itself, but may I put it this way? Our job, whether we are chemists or engineers, chemical engineers,

accountants or, in fact, in any supervisory position in industry, is to see that our actions result in the provision of the goods and services needed by the community with the minimum consumption of real resources; and the common yardstick, imperfect though it is, by which we may assess the value of our contribution is undoubtedly that of cost.

On the capital side you know, of course, that many American firms insist on the fullest possible planning of construction before one dollar is spent on materials, and they do this in order to ensure that capital, once committed, is made to earn a return as quickly as possible. I think this is a very important matter and no doubt you join me in feeling that we in Britain could pay more attention to it, despite the many problems which beset us.

There is reason to believe, too, from the capital investment figures in our report, that the average technical graduate in the British heavy chemical industry is at present supervising the erection, and indeed the operation, of from one and a half to two times the physical amount of plant and equipment for which his American counterpart is held responsible, and in Britain he certainly has, in addition, three times the number of men to supervise. Perhaps therefore it is not surprising that we in Britain often make less use than we should of our cost information, for many of us have so little time to do all that we know should be done. I would like to return to this question of adequate technical strength in a few moments.

2. Work study

May I turn now to another subject which gave rise to at least two recommendations in our report—work study. Some of you will perhaps know a good deal about this, others perhaps very little. I am glad to be able to tell you that our recommendations have been energetically taken up by the Association of British Chemical Manufacturers, who have organised a two-day conference on work study.* This conference is to be attended by over 500 senior representatives of the heavy chemical industry, and I am confident that it will lead to a better appreciation of the vital part which these techniques—method study and work measurement—can play in our industry. If this lead by the A.B.C.M. is actively followed up by the individual companies, we shall be well ahead of the American chemical industry in this very important approach to increased productive efficiency.

Why do I say very important? May I put it this way? You probably know, and indeed it is fully discussed in our report, that the American heavy chemical industry has a far higher percentage than we have of *modern plant*, incorporating many recent advances in chemical engineering knowledge. Since our return from the States my information is that this trend is

*This took place at Buxton, early in October.

accelerating. Despite the very vast expenditure which is being undertaken in the British chemical industry, the American has a three times greater capital investment per employee than we have here at home. I need not emphasise the significance of these figures to an audience such as this. Now capital for expansion and modernisation must, of course, ultimately come from the so-called profits of industry, and so our most pressing task today is to increase the productive efficiency of our existing resources. One of the most powerful ways of doing this is to make the fullest possible use of work study, applying it to what we have now and then, when we have by its use accumulated some savings, applying work study to our proposals for spending those savings, to ensure that we get from them the greatest possible productive efficiency.

How can work study help the chemical engineer? Briefly, its use at the layout and design stage will almost certainly reduce the area required for a given output, with all that means in avoidance of line losses and in reduced overheads. Frequently it can eliminate a lot of materials handling and should, therefore, always precede any capital investment in mechanical handling equipment. Its use will lead to the best grouping of operating controls and to the most economic manning of the plant and it is, of course, essential to any proper system of scheduled and planned maintenance. These are but a few examples of the importance of work study, and I would earnestly counsel those who are not familiar with these techniques to repair this omission as speedily as may be. There will be an excellent opportunity of reading of the application of work study in the heavy chemical industry when the proceedings of the Buxton conference are published by the A.B.C.M.

3. Interchange of technical information

The American is generally less secretive about many technical matters than we are. I believe this is because he has found that giving information to his competitors not only results in a valuable interchange of ideas by which he can check up on his own progress, but acts also as a constant spur to himself to keep ahead. We were impressed, for instance, by the thoroughness with which the American Manufacturing Chemists' Association collected and published technical figures of capacity, output and performance, etc., for a wide variety of chemical manufactures. The British heavy chemical industry has just nothing to compare with these publications and, as a result, we are in a poor position to judge our own technical progress relative to that of our competitors at home and overseas. I am hopeful that we may see in the next few years an attempt to make much more technical information available, and I am sure that, without any sacrifice of essential commer-

cial security, it will be possible for the weaker firms to benefit from the knowledge of the stronger by this means. It is in such work as this that the various technical and trade organisations can play a most important part in raising the standard of productive efficiency of our industry. Frequently on our tour of the American chemical factories we saw little that was new to us, but we saw far more use being made of the best. I believe that, if the level of productive efficiency of the least efficient British chemical factories could be raised to that of the best, we should find ourselves level pegging with the Americans. And it is through interchange of technical information—of what we already know at home—that this can be done.

4. Technical strength

Sir Harold Hartley in his talk stressed repeatedly the necessity of increasing the numbers of chemical engineers available in this country. Our team saw clearly that nearly every recommendation made in their report required for its implementation one or other type of technical graduate and, therefore, as our prime and overriding recommendation, we called for an immediate increase in technical graduate strength throughout the heavy chemical industry. In this we did not confine ourselves to chemical engineers, for we believe, and I think rightly, that all types of technical training has its appropriate and essential part to play. In America, as you know, we found in the heavy chemical industry that the ratio of technical strength to payroll strength was 1:6, whereas in Britain it is 1:16. I do not blame our universities and technical colleges for this, for I am sure that if, in the past, industry had called loud and long for technical men, they would by now have been forthcoming.

Why didn't we? Or rather should I say, why didn't we all? For some of us certainly did. Personally I am coming to the conclusion, with which you may entirely disagree, that we were afraid. And perhaps many of us still are afraid. Afraid of what? Of overstaffing?—but have you yet found a chemical factory in which an additional engineer or chemist or chemical engineer could not save at least twice his own salary? Of the cost?—but is there any more expensive way of running a factory than by denying it adequate technical leadership? Could it rather be that, perhaps instinctively, we are afraid, just as the humblest shop floor worker is sometimes afraid, of change, of increased responsibility, of 'being shown up,' yes and even—remote though it may seem—of losing our jobs? I hope it is fear, for I am not aware that we in Britain lack courage when we know where the enemy lies. And if there is one use for courage in British industry to day it is in refusing to be denied adequate technical strength, so that the undoubted genius of our scientists, and the

pride and skill of our craftsmen, may be directed with all speed to the provision of the goods and services which it is industry's prime duty to provide.

Fractional Distillation

(Concluded from page 352)

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ULTRASONICS IN INDUSTRY

A Critical Assessment

I. Methods of Generation

By M. H. M. Arnold, B.A., B.Sc., F.R.I.C., A.M.I.Chem.E.

Ultrasonics is suffering from popularisation; the more spectacular demonstrations and the less cautious speculations are inflated into proven processes of immediate commercial attractiveness. The subject is one of considerable technical difficulty, both from the theoretical and the experimental aspect, and its practical development has been distorted by the fact that the bulk of the work has been carried out by the electrical industry, with a corresponding over-emphasis on electrical methods of generation, and a certain detachment from the general requirements of less-specialised industries. There is a large gap between the maker and the potential user. The maker does not know what is required and the user does not know what is available. There would thus seem to be room for a critical appreciation of ultrasonic applications in industry, with stress being laid on potential and developing applications rather than on those relatively few which are well established. The chemical engineer is concerned with ultrasonics both as a means of obtaining information, e.g. flaw detection, and as a means of producing chemical and physical effects. Therefore he should find it rewarding to read this evaluation of the present status of ultrasonics in industry. In this first article the author discusses methods of generation—mechanical, thermal and electrical—focussing, and transmission through phase boundaries. In his second article he will consider the industrial applications of ultrasonics.

SINCE we are considering ultrasonics as a tool, rather than ultrasonics as a technique, it is not appropriate to discuss methods of generation in detail. But a brief account is necessary so that the scope, cost and efficiency of the various methods can be assessed. It cannot be too strongly emphasised that the primary barrier to the adoption of any new process is an economic one. Even if a new process can do something which has never been done before, the question still arises if it is worth doing at all. And if it is to be competitive with established processes, then it must show an advantage in capital cost, running cost or in one of those secondary economic items such as simplicity, reliability or safety. It is only very recently that this fact has dawned on the supporters of ultrasonics. As a result, there are few ultrasonic generators which are even remotely satisfactory as productive plant items.

Ultrasonic waves are a type of sound waves—that is, they are longitudinal vibrations in a physical medium—of frequency so high as to be inaudible to man. The limit of audibility is usually taken as 20 kc., but individuals vary greatly, and the ability to hear up to, say, 22 kc. is not uncommon. So far as the properties of the waves are concerned, the limit of audibility is irrelevant, and there are some applications where the lower-frequency limit is set by considerations of comfort rather than of efficiency.

Table I sets out the important characteristics of the different methods of generation. Most of the data has been

Table I. Characteristics of Ultrasonic Generators

Type	Medium	Maximum power (watts)	Maximum intensity (w./sq.cm.)	Frequency range (k/cs.)		Efficiency (per cent. of input)
				Minimum	Maximum	
Piezo-electric	Solid	2,000	45	100	150,000	25
Magneto-strictive	Solid	5,000	20	8	60	Oscillator: 15-25 Condenser: 25-40 Poulsen arc: 25-40?
Whistle	Gas Liquid	200 2,000?	1? ?	Sonic Sonic	200 40	3-5 5-15?
Siren	Gas	50,000	10	Sonic	200	20-70
Holtzmann	Solid	15?	?	Sonic	35	?
Electro-magnetic	Solid	?	?	Sonic	40	20-30
Thermal	Gas	?	?	Sonic	2,000	?

(All values are of necessity approximate and indicative only)

obtained from Bergmann's 'Der Ultraschall' (Hirzel Verlag, Zürich); this is a most lucid and comprehensive book, which includes well over 2,000 references to nearly all aspects of ultrasonics. The methods may be conveniently grouped as mechanical, thermal and electrical.

Mechanical generators

(1) **Whistles.** The various types developed all depend on the setting in resonance, by a shaped stream of fluid moving at high velocity, of a metal tongue or a fluid column. They require precision in design and manufacture, but are very robust, simple and compact, and are applicable both to gases and liquids. The

ultrasonic vibrations are developed in a moving body of fluid; this may or may not be disadvantageous. At the moment the efficiency is low, and it remains to be seen if this will be outweighed by their undoubted advantages. In considering the efficiency it must be borne in mind that the pump or compressor which supplies the operating power need not be driven by an electric motor. If a cheaper source of rotational energy is available, as may commonly be the case, the overall efficiency is to that extent raised. Although the unit size is limited, whistles are clearly very suitable for multiple-unit operation. The most efficient liquid whistles are the only types of ultrasonic generator which

can be really regarded as industrial plant.

(2) **Sirens.** The principle is the same as that of an ordinary siren, but the high angular velocities involved imply precision design and manufacture. Their main advantages are high efficiency, more or less unlimited unit size and a low capital cost per unit of power. So far as is known, they are restricted to use in gases and, like whistles, the vibrations are set up in a moving fluid stream. Although frequencies up to 200 kc. have been obtained, they are normally operated in or only slightly above the sonic range, and this obviously restricts their scope. It should also be borne in mind that any generator developing high vibrational amplitudes in air is a potential health hazard.

(3) **Holtzmann generator.** In this method a rod is set in vibration by longitudinal friction, as by the rubbing of a moving belt. The method is too undeveloped for an accurate assessment, but it is not remarkable for elegance.

Thermal generators

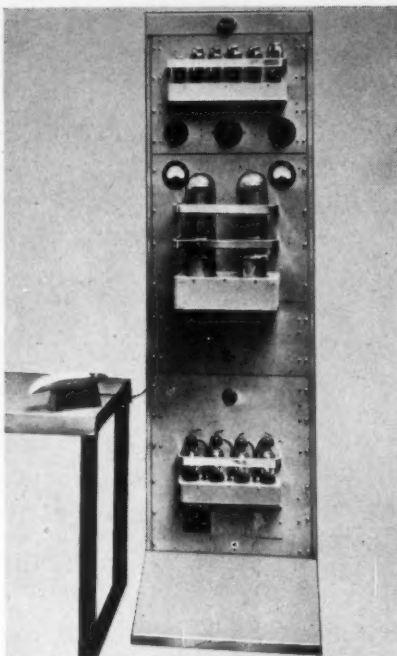
Types of generator have been devised in which vibrations are developed in a gas by the rapid temperature (and therefore volume) changes of an electric arc carrying an alternating current of appropriate frequency. Their only interest appears to lie in the very high frequencies which can thus be developed *directly* in a gas.

Electrical generators

(1) **Electromagnetic.** Conventional loudspeakers are not suitable for ultrasonic generation because of the difficulty or impossibility of obtaining resonance of the moving member at such frequencies. The St. Clair generator overcomes the difficulty by having between the pole-pieces of the electromagnet a moving member which is integral with a massive cylindrical metal block mounted above. Longitudinal resonance is set up within the cylinder. This method is attracting considerable attention at the moment, but its advantages are by no means clear.

(2) **Magnetostrictive.** Magnetic materials exhibit the phenomenon of changing slightly in length when magnetised. So, if a nickel tube is wound with a solenoid through which an alternating current is passed, it will vibrate longitudinally, resonating if the electrical frequency is matched to the natural frequency of the tube. In practice the 'transducer' is usually made of a bundle of laminae, and is fed with an alternating superimposed on a direct current. Such transducers are robust and easy to handle, and may be built up to large sizes. The frequency range is limited in both directions by mechanical considerations of transducer length.

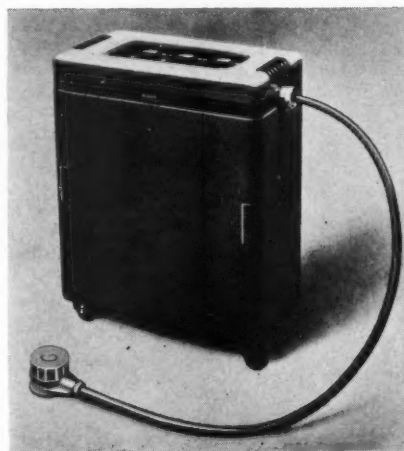
Usual practice is to produce the high-frequency current by a valve oscillator. Such oscillators, besides being complicated, expensive and fragile, are not particularly efficient converters of energy, running at



Magnetostrictive ultrasonic generator.

about 50% efficiency. The Poulsen arc, which was used in radiocommunication before the invention of the thermionic valve, offers a means of generating large amounts of high-frequency current at an efficiency around 75%, but suffers from the disadvantage of being unstable in both frequency and amplitude. But it has been found that the circuit is sufficiently stabilised if it is coupled to a magnetostrictive transducer in resonance with it, and it would seem that the development of this method would afford a much cheaper and simpler source of ultrasonic power. So far as is known, the method is not receiving active attention.

If intermittent rather than continuous radiation can be tolerated, or is desired, it is sufficient to use a device which will



[This and photo above: Mullard Ltd.]
Piezoelectric ultrasonic generator.

alternately charge a condenser and then discharge it around the transducer. If the system is in resonance, the result is to produce a succession of damped pulses of vibrations. The duration of each depends on the damping characteristics of the system and is usually of the order of 1 millisecond; the interval between pulses depends on the timing of the commutating device and is usually of the order of a second or so. This method is of high efficiency and is extremely cheap and simple.

It has been suggested that alternating current of the required frequency might be obtained directly from a suitably-designed alternator, and such an alternator could no doubt be designed. But the step from the normal 50 c. to the desired 25 kc. is a large one and the amount of detailed development work needed could only be justified by a much greater demand for ultrasonic energy than exists at present.

(3) **Piezoelectric.** Sections of certain crystals—quartz is the most commonly used—alter in thickness when a potential difference is applied across them. So an alternating current yields a mechanical vibration of the crystal slice, with an extremely sharp and intense resonance when the electrical and mechanical frequencies are matched. Because of this sharpness of resonance quartz crystals are, of course, extensively used as frequency stabilisers in wireless transmitters, and it is largely for this reason that far more is known of the piezoelectric effect than of any other method of ultrasonic generation. An inevitable result has been the over-estimating of the relative scope and importance of this particular method.

The piezoelectric generator operates up to 150,000 kc., and its lower limit of about 100 kc. is already on the high side of other generating methods. Since the crystal is driven by a valve oscillator, the overall efficiency is not outstanding, and the very high voltages which need to be applied across the crystal (up to, say, 30,000 v.) raise difficult questions of insulation and mounting. Nevertheless, the very uniqueness of the piezoelectric frequency range makes these considerations largely irrelevant.

(4) **Electrostrictive.** Barium titanate crystals exhibit the electrostrictive effect of changing their dimensions in an electric field. There is thus a certain similarity to magnetostriction, with the difference that barium titanate will vibrate with equal efficiency in any direction. This means that a polycrystalline aggregate—a ceramic mass, in fact—can be used as a transducer and that extremely complex shapes can be made cheaply and operated efficiently. Against this, ceramic transducers inevitably lack thermal and mechanical robustness and are difficult to attach.

Not much is known as yet about electrostriction generators. They resemble magnetostriction generators in frequency range, power and efficiency and would

seem likely to have a considerable future in limited fields.

Focussing

Provided that lenses and mirrors of appropriate size and composition are available or, alternatively, by the use of concave transducers, it is possible to focus ultrasonic waves in the same way as light waves. In this way intensities as high as 5,000 w./sq.cm. have been obtained, and it is not surprising that some very spectacular effects can be demonstrated. The industrial potentialities are unexploited, but the possibilities inherent in such a detached and localised power concentration are obviously immense—even apart from any specifically ultrasonic effects. It may be noted that focussing arrangements do not involve any great additional complication of an ultrasonic installation.

Transmission through phase boundaries

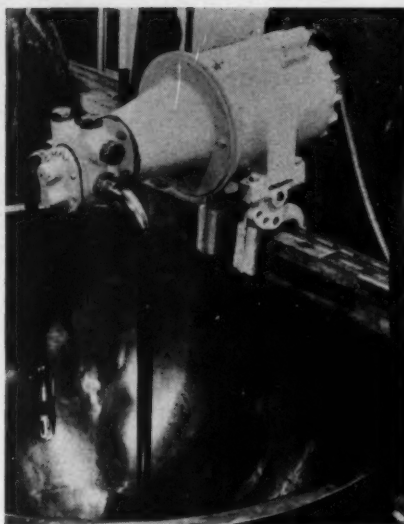
The behaviour of ultrasonic waves at a phase boundary is not a simple subject and really requires a mathematical mode of treatment, but an attempt must be made to discuss it, for not only is it particularly important in itself, but also misunderstandings about the limitations of phase transfer are probably more productive of disappointment with ultrasonics than any other aspect.

Phase transfer considerations crop up typically in the following cases:

- If waves are generated in air or metal, can they be transmitted into a liquid?
- If waves are generated in liquid, to what extent will energy be lost through the walls of the container?
- Can waves be transmitted through a 'window' from one vessel to another?

When ultrasonic waves meet a phase boundary at right-angles the extent to which they are reflected or transmitted can be calculated from the acoustic impedances of the two phases (the acoustic impedance of a material is the product of its density and the velocity of sound in it, and is thus a parameter whose size is readily determinable). The greater the difference between the two acoustic impedances, the less the transmission and the greater the reflection. Thus from nickel ($\rho v = 5 \times 10^6$) to water ($\rho v = 0.3 \times 10^6$) or vice versa there is 11% transmission, the remaining 89% being reflected back, whereas from air ($\rho v = 40$) to water or vice versa the transmission is about 0.04%. These examples are typical, and it is clear that transfer even between solids and liquids is frequently none too good, while between either solids and liquids and gases it is infinitesimal.

These conclusions are valid whether or not the system is resonating, but resonance must be taken into account, since it increases, commonly several hundredfold, the radiation intensity available for phase



[Photo: Ultrasonics Ltd.]

Liquid whistle installed in a cosmetics factory.

transfer. Thus, if a medium *A*, energised with radiation of intensity 100, feeds with a transmission of 0.1% into medium *B*, the intensity in *B* will be 0.1. But if *A* comes into resonance, the transfer to *B* will be 0.1% of the resonance intensity, which may well be several hundred times greater than the energising intensity. Thus an appreciable fraction of the energy developed in *A* may be fed into *B* if *A* resonates. Theoretically, the resonance intensity in *A* could build up until all the developed energy was being transferred to *B*, but in practice resonating systems suffer internal losses and the resonance intensity never reaches a figure high enough to make liquid-gas or solid-gas transfers appreciable.

Since a resonating system, however high its intensity, can never dispose of more energy than energises it, if the percentage transmission to the second medium is appreciable, the resulting energy transfer may well be so large as to prevent any build-up of resonance. The resonance of medium *A* is thus damped by medium *B*. This can be in practice a serious disadvantage, for the maximum efficiency of generation of ultrasonic radiation is in most cases dependent on resonance between the medium in which the waves are generated and the energising force, e.g. a magnetostriction transducer with the alternating current energising it.

In the case where *B* comes into resonance a false impression of the energy transfer may be given. Even if the energy transfer is small, if *B* forms a low-loss resonance system the intensity in *B* will build up to a respectable figure; thus a quartz crystal driving into air can yield standing waves of considerable amplitude. But the amount of energy that can be withdrawn from such a system can never exceed the amount fed into it, and so the low-energy transfer is revealed by the

great susceptibility of such a system to damping and by the small amount of useful work it can do. This situation may again be obscured by the fact that it is by no means clear in many applications to what extent the waves perform work, as opposed to creating a situation in which the desired change will take place spontaneously.

When the percentage transmission is high a state of affairs may arise in which the resonance intensity in *B* becomes high enough to feed back an appreciable amount of energy into *A*. Such a feed-back will enhance the resonance of *A*, which in its turn will increase the feed to *B*. Such a coupled resonating system may be regarded as having perfect energy transfer and maximum vibrational stability. With well-designed systems it is possible to withdraw from *B* the whole of the power available from *A* without destroying the coupled resonance. Such a system is generally to be striven for, and may be attained with solid-liquid and solid-solid transfer systems.

Summing up, we may say that transfers into and out of the gas phase are impracticable unless it is merely desired to set up an unloaded resonant system. Transfers between liquid or solid and solid are practicable, best results being obtained when both phases are resonating together.

When the radiation is not incident at right-angles the situation is extremely complex and is indeed not fully worked out. We have to take into account the ordinary phase transfer principles already discussed, refraction and total internal reflection, conversion on reflection of longitudinal waves into transverse waves at certain angles of incidence, and the existence of different critical angles for the two types. All that can be said is that all these additional effects tend to militate against resonance and to increase losses, so that phase transfer at normal incidence is to be preferred for efficiency as well as for simplicity.

The behaviour of ultrasonic vibrations passing through separating plates or windows may be summarised as follows:

(a) Transmission is at a maximum through windows which are a half-wavelength thick or an integral multiple of that value, and at a minimum through windows a quarter-wavelength thick or odd multiples of that value. Below quarter-wave thickness transmission increases with decreasing thickness.

(b) When media differing in acoustic impedance are separated by a window of intermediate acoustic impedance, much more efficient transmission is obtained than if the two media were juxtaposed without the interposition of the window.

In the second article, the author will discuss the applications of ultrasonics, dividing them into two distinct classes: instrumental (flaw detection, thickness measurement, viscometry, etc.) and operative (emulsification, flocculation, dedusting of gases, etc.).

Wastage of Energy in Factories

In our last issue we reviewed the new British Productivity Report on Fuel Conservation. We now present part of the report that discusses in detail measures that can be taken to avoid the very heavy waste of steam in factories, a matter of especial importance to the chemical industry.

IN many British industrial plants the wastage of water, steam and electricity, as well as other service supplies, such as gas and compressed air, etc., adds up to something formidable in terms of the fuel required to provide them. A full appreciation of this loss leads to the conclusion that the major economies in fuel are, in fact, more likely to be achieved in the factory than in the boilerhouse.

It has been estimated that the fuel consumption of manufacturing industry in the U.K. might well be reduced by something of the order of 30% if measures were taken to utilise efficiently the different works services dependent for their production upon fuel of one kind or another. An example from a British industrial plant may be cited. At one stage in its development it was equipped with modern water-tube boiler plant capable of an efficiency of about 85%. Following its installation, investigation showed that of the total amount of steam delivered to the factory for process purposes only some 25% could be traced as usefully employed in production. Such a state of affairs, by no means uncommon, is highly deplorable.

Responsibilities of works engineers

The proper use of steam, heat and power and the other works services involving the burning of fuel is very much a matter of management and organisation. Too often in British plants the responsibilities of the engineer begin and end in the boilerhouse, except in so far as they concern works maintenance; he has seldom any voice in production. It cannot be over-emphasised that the efficient use of heat and power is a matter of specialised technical skill.

The works engineer should be involved equally with the production manager in all matters relating to process, whether it be in the operation of existing plant or in the planning of new equipment. Only in this way can full advantage be taken of the known methods of achieving efficient production with proper economy in the use of fuel and power.

In the U.S. the relationship between the engineer and management appears to have been established on a much more satisfactory footing than is generally the case in the U.K. The results were apparent to the team in the different factories visited.

In the steam-consuming industries it appears that, so far as pipework arrangement, steam trapping, air venting, insulation, instrumentation, etc., are concerned, developments are much the same in the U.K. as in the U.S. There is some evidence, however, that greater care is taken in the U.S. in these matters, particularly with regard to convenient layout

of plant and its general finish, presumably from the thought that 'a job that looks well is in fact well done.'

Residual heat losses

There is a tendency in the U.S. to increase the pressure at which steam is generated; boiler pressures are generally higher than in the U.K. This tendency in the U.S. is reinforced by the desire to step up the rate of output. This aim is, of course, secured by increasing the temperature difference between the heating surface and the material passing through process. The use of steam pressures and temperatures in excess of what is actually required, however, inevitably means increase in the several residual heat losses.

Industrial products on completion have inevitably to be cooled down to atmospheric temperature, and therefore if they leave the process plant at a temperature higher than is absolutely necessary it is clear that they will carry away with them a considerable amount of excess heat which has to be dissipated, as it is seldom possible to recover it by any process of interchange. In addition, where steam is used indirectly as, for example, in a jacketed pan, the temperature of the condensate and the heat carried away by it rise as the steam pressure is increased.

Most industrial processes use only the latent heat of steam, which at 200 p.s.i. represents 70% of the total heat, whereas at atmospheric pressure it represents 84% of the total heat. It is clear, therefore, that an increase in process pressure must result in an increase in heat loss in the discharged condensate.

Effect of reducing process steam pressure

In the U.K. the tendency, except in special cases, is to reduce process pressures and, if necessary, increase the amount of heating surface in order to counteract the effect of decrease in temperature differential. This results in much more efficient usage of the heating surface and achieves a substantial saving in fuel, particularly by reduction in temperature of the condensate. For example, in a factory using steam for indirect heating, reduction in process pressure from 100 to 20 p.s.i. would reduce the coal consumption by about 6%, assuming that the condensate is discharged to drain without heat recovery, as it is in many cases. There can be no doubt, therefore, that from the point of view of fuel economy reduction in process pressure is more logical than its increase, and industrial engineers in the U.S. might well study trends in this direction in the U.K.

As to the question of reducing process steam pressure generally, it is surprising what can be done without in any way handicapping the rate of output of a factory. There are many cases on record in the U.K. where the whole of the steam supply system in a works has been reduced to 15 to 20 p.s.i. without in any way curtailing production, and with considerable gain so far as fuel economy is concerned. In special circumstances the general reduction of steam pressure in a factory may be difficult owing to the fact that the steam mains are restricted (which can be readily overcome) or that one consumer requires steam at high pressure and sometimes at a pressure in excess of the boiler pressure. This latter condition can sometimes be met by the installation of a steam compressor to supply the odd consumer, provided its steam demand is relatively small.

Generation of back-pressure power.

A highly important aspect of process steam pressure is the generation of back-pressure power from process steam. The subject is dealt with generally in another part of the report, but here it may be stated that over the normal range of pressures a reduction of 10 p.s.i. in process pressure is equivalent in terms of back-pressure power generation to 100 p.s.i. increase in boiler pressure. This is highly significant in the U.K., where many industrial plants are still equipped with low-pressure Lancashire boilers. In a great many factories reduction in process pressure makes it practicable and highly economical to install back-pressure power generating plant without the immediate need for installing high-pressure boilers.

Accurate control of steam pressure

The accurate control of steam pressure is a fundamental necessity in most industrial plants, although this is not always realised, and where the process pressure is low control must obviously be very close, since less margin is available to cover downward variations of pressure. There are several possibilities: (a) automatic combustion control at the boiler, (b) pressure regulation in the steam mains and (c) thermal storage of one kind or another.

(a) Automatic combustion control.

Where the steam demand does not vary a great deal and the peaks are of long duration, developing and falling off slowly, automatic combustion control (described in Chapter 13) may adequately meet the case, bearing in mind that this class of equipment cannot provide control of the conditions beyond the maximum steaming capacity of the boilers engaged, while the

system depends upon an increased evolution of heat in the furnace and an increased evolution of steam in the boiler to meet a peak. This takes time to accomplish. A certain lag in the response to automatic combustion control is therefore unavoidable. The lag is, of course, less with spreader stokers and still less with pulverised fuel, gas or oil firing—hence the popularity of the system in the U.S., where these fuels are widely employed for boiler firing and where, in fact, automatic combustion control is very commonly employed. So far as solid fuel firing is concerned there is the advantage in the U.S. over similar equipment in the U.K. of a consistent and dependable supply of fuel.

(b) **Pressure regulators.** The use of regulators in the distribution of steam throughout a factory is, of course, necessary where different pressures are employed. They usually take the form of reducing valves of one kind or another, preferably fully compensated to avoid hunting. It is to be borne in mind, however, that automatic regulators in themselves do not suppress steam peaks but only pass them on to the higher pressure range with which the regulators are interconnected. In stabilising the steam pressure on a low-pressure group of consumers the use of reducing valves or regulators may therefore handicap other groups of consumers operating at higher pressure. To this extent the system by itself can be employed effectively only where the steam demand is relatively constant.

(c) **Thermal storage.** So far as accurate regulation of steam pressure is concerned, both automatic combustion control and simple reducing valves therefore have their limitations and, where the steam demand varies widely, with peaks that develop and fall off with great rapidity (a condition common enough in industry), something more is needed in the shape of a source of, and a sink for, thermal energy—in fact, a thermal flywheel that will absorb surplus heat when it is available and regenerate this heat when the demand exceeds the capacity of the boiler plant.

There are two types of heat storer: the steam accumulator and the hot-water accumulator. Developments have gone very much further in the U.K. than in the U.S., probably because in Britain industrial steam requirements are in the main met by Lancashire boilers, which are sluggish in meeting a varying steam demand.

It is beyond the scope of this report to discuss such equipment in detail, but the considerable number of steam accumulators and hot-water accumulators installed in British steel works, textile factories, sugar refineries, laundries and breweries have demonstrated the important value of thermal storage as a means of providing accurate steam pressure control and avoiding the impact of heavy peaks on the boiler

plant. Such installations have shown a reduction in coal consumption of 10 to 15% with an increase in factory output of a similar order, and an improvement also in the quality of the finished product, due to the accurate control of steam pressure.

Control of peak demands

Much of the harm done in an industrial plant by allowing heavy steam peaks to develop could be avoided if work was properly scheduled and large consumers were brought into operation in sequence instead of simultaneously, particularly at the beginning of each shift. Altogether too much freedom is given to factory operatives to open and close steam valves without regard to the effect this may have on productive efficiency and fuel economy. A greater degree of control and a better understanding of all the implications would most definitely improve productivity in every sense of the term.

Return of condensate

The return of condensate from the factory to the boiler hot well is a subject which appears to have been much more widely studied in the U.K. than in the U.S., as one having an important bearing on fuel economy. Where it is practicable, all condensate should be collected and returned to the boiler, or otherwise usefully employed, conserving both the water and its heat content. For example, in a factory using steam for indirect heating at 20 p.s.i., the complete recovery of all the heat in the condensate for boiler feeding or for process would yield a theoretical saving in fuel of about 16%. In actual practice, probably half this saving would be achieved, as there is considerable heat loss involved in piping returned condensate back to the hot well or to a storage tank for process purposes. Important fuel economies may often be obtained by the flashing of trap discharge from a group of high-pressure consumers to a steam main supplying a group of low-pressure consumers, and this system, too, appears to be more widely used in the U.K. than in the U.S.

In its visits to different American factories the team was struck by the fact that in a great many no attempt was made to recover condensate, while comparatively large feed water-treatment plants were installed in order to provide anything up to 100% of make-up. In this respect the difference between American and British practice is most pronounced. It is true that the problem of using condensate effectively is one fraught with difficulties that may have hindered its wider employment. The important point here is that if condensate is to be used for boiler feed it must be pure. Unfortunately, many industrial condensates are contaminated by the product and are therefore unsuitable for boiler feed without treatment, which is often difficult and, indeed, sometimes impossible. In addition, returned

condensate may be highly corrosive. Even so, its valuable heat content can usually be recovered by making use of a suitable form of the many types of heat-exchanger plant now available.

Waste heat recovery

Most industrial processes that use heat reject a proportion of it in the form of gases, vapours, hot effluents or cooling water, a great deal of which can be economically recovered. The recovery of waste heat in its technique and practice is well understood and recovery installations are common in British industry. There is still, however, great scope for fuel economy in this direction, and industrialists should investigate the subject more closely. Recent developments in heat-exchanger plant have made it possible to recover useful heat from hot effluents without incurring the risk of contamination or the consequences of corrosion, and this source alone represents a substantial possibility for saving coal. In the same way it is gratifying to note the trend towards the recovery of low-grade heat from vapours, e.g. from dye vats, brewing coppers, evaporating pans generally and paper-drying machines.

Heat recovery from high-temperature gases has been widely practised for at least half a century and it is a matter of some surprise that many industrial plants in the U.K. have not taken advantage of it. For instance, the simple and well-known feed water economiser which will reduce coal consumption by anything from 10 to 15% could be more widely applied, especially as with present-day fuel prices its cost can often be recovered in about two years. The same comment might apply equally to the well-known principle of regeneration and recuperation applicable to metallurgical furnaces and kilns.

The waste heat boiler is another common means of recovering heat from waste gases of industrial furnaces, gas works and internal combustion engines and, although its use is more widespread in British industry than in American, we have by no means exhausted the possibilities in this direction. We again strongly recommend that industry, particularly heavy engineering, should investigate more closely the economics of the waste heat boiler. The interested reader should study the many examples given by Crichtley, Fehling and other authors in a publication issued by the Institute of Fuel and entitled 'Waste Heat Recovery.'

The economics of the problem merit more extensive treatment than can be given in this report. All that has been attempted is to outline the possibilities which lie in this field and to indicate that the potential fuel saving is very substantial and should be pursued.

Drying

Almost all manufactured products are dried at some stage in production, and

many undergo several processes of drying and re-drying in their progress from raw material to the finished article. It is only of recent years that we in Britain have grown to appreciate the amount of fuel used for this purpose, and investigations made into various drying processes indicate that, by and large, they are operated at low efficiency. The Ministry of Fuel and Power set up a committee in 1948 to study the subject and to find out where economies could be achieved; this committee estimated that the average efficiency of drying processes at that time was no greater than 30%, and since then a wide examination of industrial drying processes has confirmed that substantial improvements in drying efficiency up to perhaps 50% are possible. In 1951 the Institute of Fuel effectively focussed these studies in a valuable symposium embracing all the major drying processes employed by industry. All operators of drying processes on any appreciable scale would be well advised to obtain a copy of the proceedings. In recent years considerable advances have been made in drying techniques both in this country and the U.S., notably in the application of electricity at high frequencies and of infra-red rays and also, particularly in the U.S., in applying the products of combustion or even a flame direct to the material.

Any process of drying consists in the extraction of surplus moisture either by the application of heat, by mechanical separation or by a combination of both. Mechanical separation is carried out either by direct pressure suction or centrifugal action. Thermal drying plant takes many forms, but the underlying principle of all is to heat the goods to be dried in an atmosphere which is maintained below its moisture-saturation point. Of the two processes, mechanical separation is by far the more economical from the fuel aspect and it is doubtful whether British industry exploits it to its full extent.

The most economical combination of the two systems must be determined by careful investigation into the particular requirements; often in the past the relationship has been largely a matter of guesswork.

Recently there has been an inclination, particularly in the U.S., to introduce control in connection with drying processes. Automatic control ensures not only a balanced product but usually a heat input commensurate with what is actually required (over-drying is a common fault). There are very few drying appliances which cannot be effectively controlled by instruments and it would be well if manufacturers discussed their drying problems with the instrument makers. Where a product is subject to more than one heating cycle, important economy would result if the plant were arranged so as to limit the loss of residual heat in the product itself between one cycle and the next. As drying processes are being applied in ever-widening fields, including agriculture (for

the drying, for example, of grass and grain), it becomes all the more important to ensure maximum efficiency in the use of both energy and fuel.

While it is gratifying to learn of the widespread investigations that are being made in Britain into drying processes and their related problems, it is urged that the movement should be speeded up in view of our pressing need for fuel economy.

High-temperature hot water

A development of recent years that is worthy of comment here, particularly in relation to the projection of new factories, is heat distribution by hot water at high temperature instead of by steam. In this system water is circulated in a closed circuit under pressure, so that high temperatures can be used without boiling. It has many advantages over a steam distribution system, and where it can be suitably applied it results in noteworthy savings in fuel.

The high-temperature water is circulated by means of an electrically-driven pump, and consequently all the heat-consuming equipment receives its heat at the maximum desired temperature, which can be regulated within fine limits by mixing flow and return water as required—a feature of great advantage, particularly in space-heating systems where steam temperatures below 212°F. involve the use of a vacuum system.

On the Continent and in Britain there have been considerable developments of this system and several hundred plants have been installed which provide ample and authentic evidence of its advantages and limitations. On balance, we advocate a wider and more general use of high-temperature hot-water systems as opposed to steam, particularly for new factories, because of (a) greater uniformity of temperature distribution, (b) accurate control of temperature over a wide range, (c) elimination of feed water conditioning and corrosion of pipelines, (d) elimination of steam traps and condensate recovery problems and (e) ability to meet fluctuating demands due to the inherent high thermal storage capacity of the system. The possible disadvantages are (a) higher initial capital cost and (b) complexity of conversion from an existing steam system.

Thermal insulation

In the conservation of fuel there is probably no single factor that has such common application in industry and is more important than insulation. The function of thermal insulation has been understood for a very long time, almost from the first introduction of steam to industry. It is all the more remarkable, therefore, that the financial benefits which would accrue to industry by the elimination of preventable heat loss by means of effective insulation have not received greater recognition.

Insulation takes many forms and demands a variety of materials to fulfil the different conditions that have to be met.

Its most common use is perhaps in the field of steam engineering where, since one type looks very much like another, much of the insulation applied falls below a good standard and still allows preventable heat losses.

It is not the purpose of this report to go into the details of different forms of heat insulation or into the qualities of the different insulating materials in common use. The subject, however, is of such wide importance that the team feels that it cannot avoid reference to it in general terms and mention of the great possibilities for fuel saving that it presents.

In steam engineering. We hold the view that in steam engineering alone, where insulation is a commonplace, there is considerable scope for quite substantial gains in fuel economy if existing installations were to be investigated to determine where preventable heat loss is occurring.

In high-temperature installations. In a second field—that of high-temperature insulation—it is only in recent years that serious attempts have been made to prevent heat loss from the wide range of furnaces used in metallurgical processes and from other high-temperature equipment such as kilns, drying ovens, etc. It has been stated that furnaces insulated to the optimum degree would reduce fuel consumption by at least 20%, apart altogether from other advantages arising from stabilised temperature conditions.

In buildings. A third and very important sphere for the application of insulation, and one of still more recent development, is that of buildings. In Britain in particular insulation has not been considered one of their essential features, notwithstanding the potential fuel savings or the improved amenities that result. In the U.S., on the other hand, thermal insulation of structures has been common for many years, perhaps because of the climatic conditions and the demand for higher standards of comfort both in the home and in the factory. The team saw many examples of factory construction where insulation had been developed to a remarkable degree of efficiency.

The pressing need for fuel economy in recent years in Britain has stimulated its application to both new and existing buildings, with markedly beneficial effects. Progress in this direction is so clearly desirable that it should be expedited by every possible means, with the ultimate objective of making every structure requiring heating conform to a recognised standard of thermal insulation.

British industry uses perhaps 30% or more of its total fuel consumption purely for space-heating purposes and, although no accurate measure of the overall savings that structural insulation would give is available, we believe a substantial proportion of this outlay could be saved.

The cost of such insulation represents an investment attractive to the factory owner, inasmuch as the amount of fuel saved is sufficient (ignoring abnormal

taxation) to repay it in under four years, and in a new structure there is the added benefit of the reduced capital cost of the heating installation itself.

The magnitude of the potential coal saving by structural insulation can be gauged by the simple example of the common corrugated asbestos cement roof which, if lined with $\frac{1}{2}$ -in. insulating board with an air space between the lining and the roof, shows a saving of 6 tons of fuel for every 1,000 sq. ft. of roof area p.a. If glass wool, bitumen-bonded, is added and interspersed between the fibre board, the fuel saving is increased to between 7 and 7.6 tons per 1,000 sq. ft. for the heating season, a saving which might well amount to half the previous cost of heating the building.

While domestic habitations were not within the compass of the team's investigations, it is equally true and important that a recognised standard of insulation should be considered essential to this type of building, again taken solely from the point of view of fuel economy. In recent years much research has been undertaken in Britain and a great deal of information has been published that it is hoped will be put to good use.

In an uninsulated house at least 25% of the heat escapes through the roof and ceiling construction, and about 70% of this loss is prevented if the roof is insulated in a simple manner, i.e. by placing a simple, cheap and convenient form of insulating material between the roof rafters and above the ceiling. If we take glass wool as a good example, this material, felted with bitumen to a convenient mat which can be draped over the ceiling joists, can save 90 therms of the heat output of a normal three-bedroom house per heating season of 33 weeks for an expenditure of under £10. If, in addition to the roof insulation, the walls of a dwelling are effectively insulated, then the saving per heating season would be of the order of 130 therms.

Heat insulation and fuel saving

We consider the application of thermal insulation in all its forms to be one of the greatest potential sources of fuel saving, and are confident that at least some 5 million tons of coal p.a. could be saved by universal application in the three domains to which we have referred.

Literature on fuel economy

In this chapter only one or two of the main points relating to works energy wastage have been referred to and nothing has been said in detail regarding the economies that can be effected by efficient lagging, steam trapping, air venting, etc., or the measures which are necessary to conserve such services as electricity, gas and compressed air. These are dealt with adequately in the specialised technical literature published as 'Fuel Efficiency Bulletins' by the Ministry of Fuel and Power, London.

Plant and Equipment

Mixing pan provides own power for stirring gear

For what is believed to be the first time, a steam-jacketed mixing pan has been made independent of auxiliary power for driving the mixing gear. This is achieved by using the low-pressure steam raised for heating the pan to drive a three-cylinder radial steam engine mounted on the cover. The new unit has been developed by Cannon (C. P.) Ltd., who say that, apart from the saving in power, considerable economies are also made in the total installation by the elimination of electric wiring and motors, shafting and belting or any other auxiliary drives.

The steam drive provides mixing speeds from 1 r.p.m. to any speed likely to be required. Other features of the unit are that it is flameproof, unaffected by chemical fumes and works normally under any climatic conditions. The stirring gear has been designed to drive mixing pans with capacities from approximately 100 to 500 gal.

The engine is of the single-acting type, the cylinders and crank case being cast integral in heavy-duty cast iron. Steam is distributed to the cylinders by 'D' slide valves. The cylinders, pistons, valves and valve spindles are lubricated by a hydrostatic or displacement lubricator with sight feed which is attached to the steam manifold; lubrication of all other parts is by the splash principle.

The new propulsion unit is adaptable to existing plants.

Pre-plasticising injection moulding machine

The '1044 Autoplas' is a single-stage multi-screw pre-plasticising injection moulding machine designed and manufactured by R. H. Windsor Ltd. A larger machine, the '2044 Autoplas', is also in production.

The new machine provides for the first time a single-stage and 'in-line' system of pre-plasticising. Until now pre-plasticising units have functioned in two movements and have contained two distinct units, compared with one unit of the Windsor machine.

The consequent advantages of the new Windsor development are complete cleanliness without a trace of bleed-back; the compounding action of the pre-plasticiser gives an excellent dry colouring dispersion; easier maintenance and cleaning of those parts in contact with the moulding material and simplified colour and material change.

The complete pre-plasticising unit is fully automatic, all power being derived from the pump unit. There is separate pressurised lubrication to gear box and thrust system and three-zone heat control by controlling pyrometers.

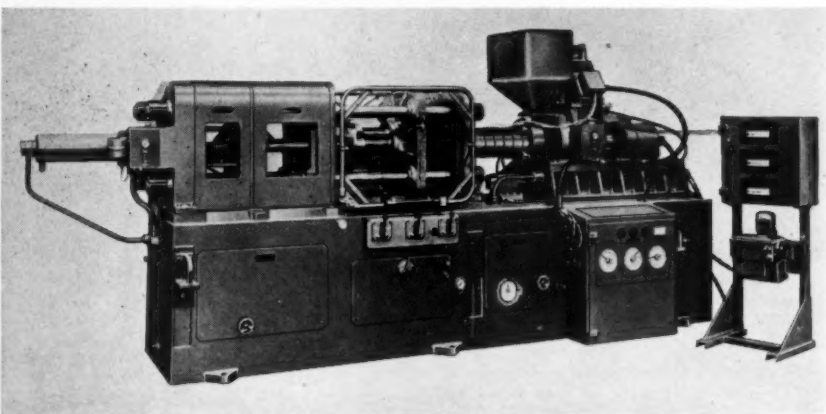
The complete unit is mounted on the Windsor retracting head.

The incorporation of this unit into the Windsor S.H.8/10 injection moulding machine enables 32-oz. (cellulose acetate) mouldings to be made, whereas the previous capacity of the machine was 10 to 12 oz. Plasticising capacity, formerly 60 lb., is raised to 140 lb./hr.

Rigid PVC for chemical plant

A new grade of rigid PVC sheet, *Vybak*, can be sawn, drilled, routed or milled on similar machines to those in the wood-working or light engineering industries. It can also be welded by the 'hot gas' welding technique. It is terra cotta in colour and can be obtained in standard thicknesses up to $\frac{3}{4}$ in. The new sheet is resistant to most chemicals other than ketones, esters, organic acids, aromatic hydrocarbons and chlorinated paraffins.

Being thermoplastic, the material can be formed by heating above its softening point and cooling in contact with the desired contour. Simple forming can be carried



Single-stage, multi-screw, pre-plasticising injection moulding machine.

out by draping the heated sheet over a male former and clamping the edges, but more complicated shapes may need male and female moulds. It is not advisable to use the sheet unsupported at temperatures above 60°C., but the makers say that up to this temperature it has excellent chemical resistance often found only in the specially alloyed metals. Other qualities claimed for it are high tensile and impact strength, good dimensional stability, low thermal conductivity, good electrical properties, non-inflammability and excellent ageing characteristics.

For welding purposes matching weld rod is supplied by the makers, Bakelite Ltd., whilst matching rod and tube are available for fabrications of pipelines, valves, etc.

Automatic control of gas producers

The importance of getting the optimum performance from a gas producer emphasises the need for applying automatic control to this process. Such control is particularly desirable in producers subjected to considerable load variations, such as those associated with open-hearth furnaces in unit installations, under which circumstances manual control would be unable to avert large fluctuations in the quality of the gas produced. In any type of installation, however, the application of automatic control will result in considerable improvement over the conditions prevailing with average manual control.

A new automatic control scheme for gas-producer plant has been devised by George Kent Ltd. The scheme covers gas offtake pressure control and blast saturation temperature control, which have been standard practice in some works for a number of years and, in addition, gas offtake temperature control, which greatly enhances the effectiveness of the whole scheme. The complete control scheme as applied to one type of gas producer, equipped with a steam-jet-blast injector, is as follows:

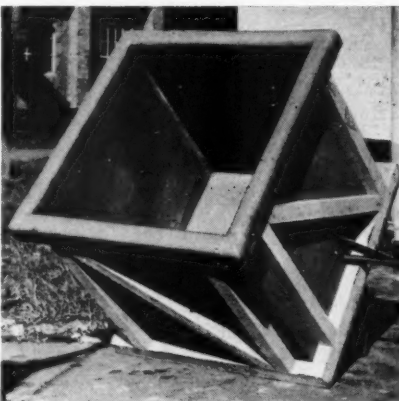
(1) *Gas offtake pressure control.* The gas pressure is detected in the gas offtake duct and measured by a low-range pressure meter containing a two-term pneumatic controller whose control signal is fed to a diaphragm-operated control valve situated in the steam main to the blast injector.

(2) *Blast saturation temperature control.* The temperature of the blast is detected by a mercury-in-steel thermometer beneath the blast hood, and is measured by a temperature recorder containing a proportional pneumatic controller whose control signal is fed to a diaphragm-operated control valve situated in the steam by-pass round the blast injector.

(3) *Gas offtake temperature control.* The gas temperature is detected by a thermocouple situated in the gas offtake duct, and is measured by a potentiometric temperature recorder containing a three-term



A steam-jacketed mixing pan fitted with stirring gear driven by the low-pressure steam used for heating and thus made independent of auxiliary sources of power.



Chemical tank in 'Vybak' rigid PVC sheet which is easily machined and welded.

pneumatic controller whose output signal is added to that generated by a load signal transmitter. The latter is a pneumatic unit installed in a steam meter which measures the pressure of the steam at the inlet to the blast injector of the producer. The combined control signal is fed through a differentiating relay to a standard Kent power cylinder, which positions the coal feed regulator, thereby regulating the rate of coal feed to the producer.

This scheme may be modified to suit certain other similar types of producer.

For further details of plant and equipment please use the coupon on page 372

Gas-purged electric resistance heating jackets

Electric heating jackets have now been marketed by the Stabilag Co. Ltd. for some years, and many hundreds are in operation. Stabilag jackets are tailor-made, uniform, resistance wire-wound heaters designed to provide for the heating of solids or liquids on a constant-heat wavelength within the infra-red range. They are particularly suitable for viscous liquids.

The demand for industrial chemical plant in glass has grown considerably since the war and, because it is now used for production purposes, it comes under the supervision of H.M. Inspectors of Factories. Recently glass plant has been used for the manufacture of highly inflammable solvents, and the Stabilag gas-purged system has been developed with the help of the electrical and chemical branches of H.M. Inspectors of Factories to protect the operators of plant against possible injury in the event of an explosion.

Because frequently the material being heated has flash and ignition points lower than the temperature of the element which is heating the liquid through the glass wall, the system provides for totally enclosing in a container the flask being heated. The lower part of the flask is jacketed with a heating jacket. The construction is such that it enables the heating conductor to be distributed with uniformity over the whole of the jacketed surface, thus avoiding the risk of the liquid being locally overheated. A container fabricated from sheet metal encloses both lower and top half of the flask and the jacket, and gas-tight joints are made between the casing and the flask. The casing is then filled with nitrogen or any other inert gas from a storage cylinder and thoroughly flushed by allowing an escape of air through suitable vents. When only nitrogen remains in the casing these vents are closed, the flow being continued until a slight pressure is built up. The flask is therefore wholly surrounded by an atmosphere of inert gas under a slight pressure. A constant-pressure feed device and safety valve are fitted to the gas storage cylinders to maintain the pressure. The heating jacket circuit connections are so arranged that they are automatically isolated in the event of the pressure level falling below a pre-set position. This is made possible by means of an automatic-pressure-level-actuated switch. This switch is held open so long as the set pressure of inert gas is maintained, but in the event of a fracture of the vessel being heated the pressure would drop instantaneously and the switch would close. To further reduce the risk of fire the gas supply system is complete with a back-pressure valve which, immediately the pressure level falls, opens to permit the gas to flow at a greatly increased rate, blanketing the affected zone to such an extent that combustion is extremely unlikely.

World News

GREAT BRITAIN

Chemical Industry's New Expansion Plan

FURTHER development plans which will cost £230 million between now and 1957 have been decided on by the British chemical industry. This expenditure is in addition to the £190 m. expansion plan announced in 1949 of which 75% had been completed by the end of last year. The industry is also increasing its annual research bill from the present £11.2 m. to £12.7 m. In 1949 this was £8.5 m.

This news was given by Mr. C. G. Hayman (The Distillers Co. Ltd.), chairman of the Association of British Chemical Manufacturers at the annual meeting last month. He also explained how the Association was trying to get the industry to use the suggestions for higher productivity made in the Heavy Chemicals report compiled by the chemical team that visited the U.S. Meetings have been held and committees set up in different areas to encourage the application of productivity suggestions. Mr. Hayman suggested that more instrumentation could increase productivity and he told members that the instrument makers were eager to co-operate in designing and supplying all equipment necessary. Work study was also important and, accordingly, the Association had arranged a conference, held at Buxton last month, at which I.C.I. experts explained work study. More scientific and technical personnel were also needed to implement the Productivity team's recommendations and the Association is to question members soon on their probable needs in five years' time so that steps can be taken to augment the supply.

Chemical Engineering Research. In the Association's report for 1952/53, it is stated that Major Bramwell, who is investigating the industry's needs and facilities jointly for the A.B.C.M. and the

B.C.P.M.A., will be submitting his report very soon. The two associations have also set up a committee to investigate the possibilities of more standardisation and simplification of chemical plant and equipment. Members of both associations have been reminded of the desirability of exchanging more chemical engineering information.

Safety. Two new tests for detecting toxic gases are being studied. One is the use of tubes of silica gel impregnated with sulphuric acid and formaldehyde for detecting benzene. The other is a test for mercury using selenium sulphide preceded by active carbon as a 'collector.' The draft Code of Practice for the storage and use of highly inflammable liquids which fall outside the Petroleum Act, has been completed and sent for approval to the Home Office.

Trade. In the first six months of 1953, chemical exports averaged £10.4 m. a month compared with £11.4 m. in 1952. Chemical imports are also down; this year they are at about the same rate as in 1952 when they amounted to £42.4 m., 36% below the 1951 figure.

Annual Dinner. Sir Oliver Franks, formerly British Ambassador in Washington, was chief guest at the annual dinner held in London on October 14. He said that special responsibility now rested upon the chemical industry for expanding national productivity. The industry was to be congratulated for its plant development and export expansion in the past few years, but it must look ahead to still further development, particularly the application of atomic energy to industry.

New Chairman. Mr. C. G. Hayman has retired after three years as chairman and he is followed by Mr. W. J. Worboys, Commercial Director of I.C.I.

The Kenfig calcium carbide factory

British Industrial Solvents, a division of the Distillers Co. Ltd., has taken a lease of the Ministry of Supply calcium carbide factory at Kenfig as from October 1, 1953, and from that date have taken over responsibility for the production and distribution of this material.

The Kenfig factory, near Port Talbot, South Wales, was started up by B.I.S. for the government in 1940 to provide Britain's only calcium carbide factory, the material having previously been imported. It has been operated by B.I.S. ever since.

Simultaneously with this news came an announcement from the Ministry of Materials stating that it ceased to trade in calcium carbide and to control selling prices on September 30. The Carbide

Distributing Agency Ltd. continues in general trading, but no longer as selling agents for the Ministry.

As the Production Department for calcium carbide, the Ministry of Materials will continue to deal with general matters concerning this commodity. There will be no change in the existing licensing arrangements for imports and exports of calcium carbide.

New instrument factory

The new factory of Honeywell-Brown Ltd. at Newhouse, Lanarkshire, was opened on September 18. A single-floor building with double-storey offices, it covers 70,000 sq. ft. The totally-enclosed stores run along the back wall and serve the length of the factory with equipment,

material and components conveniently binned as close as possible to the appropriate work station. At the end of the factory are the finishing shops and tool-room. The finishing shop is equipped with water spray paint booths and rust-prevention plant. An overhead moving conveyor carries the work from the spray booths through the drying ovens. The well-equipped toolroom, including a fully-enclosed, automatically-controlled, heat-treatment room, has produced almost every press tool that the factory uses. The machine, press, drill and metal-working shops are situated in the centre of the factory. A glass partition segregates the manufacturing section from the assembly section, thus reducing noise level and dust movement. The sub-assembly, assembly and calibration areas have dust-proof flooring and certain partitioned areas where special attention needs to be paid to cleanliness.

The new factory gives facilities to double the employment and to more than double the present output. The spare ground at the side of the factory can accommodate a further 50,000 sq. ft. of factory space.

Powell Duffryn's carbon manufacturing plans

Powell Duffryn Ltd. are to reduce and ultimately discontinue production of carbon brushes. This is disclosed in the chairman's statement for the year 1952-53. The company will, however, continue manufacture in the chemical carbon field, particularly in the production of heat exchangers and certain other products.

Windsor's acquire engineering firm

R. H. Windsor Ltd. have acquired the whole of the issued share capital of J. R. Collyear Ltd., engineers, of Alperston, London.

Messrs. J. R. Collyear and J. B. Collyear have retired from the board of the acquired company, and Mr. A. G. Dennis, LL.M., chairman of Windsor's, has been appointed chairman. Messrs. C. Norman Baker, F.C.A., R. D. King, A.R.Ae.S., and R. E. G. Windsor have joined the board. Mr. R. E. G. Windsor is the managing director of R. H. Windsor Ltd. and Mr. Baker is a director.

New units at Coryton oil refinery

A catalytic-cracking unit which uses an air lift for returning the regenerated bead catalyst to the reaction chamber will shortly be going into production at the Coryton (Essex) petroleum refinery of the Vacuum Oil Co. Ltd. Known as the *Thermofor* catalytic-cracking (T.C.C.) unit, it is the first of its kind in the U.K. A feature is that the regenerator is integral with the rest of the unit instead of being built separately. A moving-bed system is employed.

The air-lift T.C.C. process was developed by Socony-Vacuum Oil Co. Inc., of New York. An earlier T.C.C. process employed a multi-zone kiln for regenerat-

ing (i.e. burning carbon off) the catalyst. During and immediately following World War 2, about 35 of these units were installed by the oil industry in the U.S.A. and on the Continent. The first commercial air-lift unit began to operate towards the end of 1950. The T.C.C. unit at Coryton has the advantage of easier and simpler operation, combined with great flexibility, enabling a wider range of stocks to be handled. These stocks include the heaviest now being processed in any catalytic-cracking units.

Another novel feature of the Coryton refinery is the *Thermoform* continuous-percolation unit, soon to be put into operation. This unit is the first of its kind in the world and uses a clay filtering medium for removing undesirable coloured matter. The process is the final stage in the manufacture of lubricating oil stocks.

Polythene exports to U.S.

The Plastics Division of Imperial Chemical Industries Ltd. has exported to the U.S.A. 2 million lb. of polythene suitable for the manufacture of tubing. This is the first large American order for polythene secured by I.C.I. and it comes at a time of a world shortage of this thermoplastic material.

In the U.S.A., polythene tubing is finding an extensive use in water services, and extruders are unable to satisfy the demand from domestic supplies. A similar state of affairs exists in Canada, which is now buying I.C.I. polythene for tubing.

NEW APPOINTMENTS

★ **Mr. Ian McLeod**, Mem.A.S.M.E., A.M.I.Prod.E., has joined the Process Engineering Division of Sharples Centrifuges Ltd. He was formerly chief engineer of Premier Mill Corporation, U.S.A.

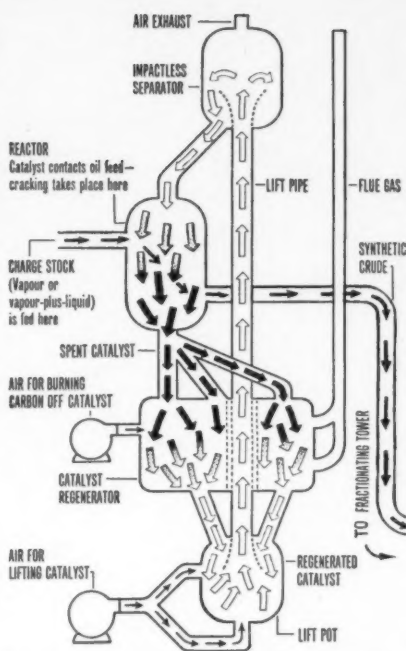
★ **Dr. A. A. Wells** has been appointed chief research engineer of the British Welding Research Association, and head of the engineering research station at Abington, near Cambridge. **Mr. R. P. Newman** will be chief administrative officer of the station.

★ **Mr. James Gray**, M.B.E., T.D., is president of the Fertiliser Manufacturers' Association for 1953-54 and **Mr. D. H. Reid** is vice-president.

★ **Mr. J. W. Napier** is chairman for 1953-54 of the Superphosphate Manufacturers' Association and **Mr. C. H. J. Corbett** is vice-chairman.

★ **Mr. J. Arnold Fox** has been appointed chairman of Price's (Bromborough) Ltd., and took up his new duties on October 1. Price's is an associated company of Unilever Ltd. To take up this appointment Mr. Fox has been released by Joseph Crosfield & Sons Ltd. and William Gossage & Sons Ltd. and he has resigned his directorships of these companies, as well as of Industrial Soaps Ltd., of which company he was chairman.

Mr. Fox joined Crosfield's in 1923. He has principally been concerned with the



Schematic diagram showing the catalyst flow in the 'Thermoform' catalytic cracking unit, referred to on this page.

sale of chemical products, in connection with which he has travelled in the United States, Canada, South America and South Africa. He was appointed to the board on September 25, 1945, and was also made a director of Gossage's on November 6, 1945. He became a director of Industrial Soaps in 1946 and chairman in 1950.

★ **Mr. S. Bailey** has been appointed chairman of Industrial Soaps Ltd. in succession to Mr. J. Arnold Fox. It is also announced that **Mr. B. G. Ross** will join the board of Industrial Soaps Ltd. as sales director.

★ **Dr. Harry Hepworth**, O.B.E., F.R.I.C., delegate managing director of Imperial Chemical (Pharmaceuticals) Ltd., retired from the company's service on September 30, 1953. He has been connected with I.C.I. and its parent companies for nearly 40 years and his name will always be associated with the formative years of I.C.(P)—for his was the guiding hand in its creation and early development.

Dr. Hepworth joined Nobels Explosives Co. in 1915 and worked at Ardeer, where he was founder secretary of the Ardeer Chemical Club. Two years after the formation of I.C.I., he was transferred to the new company's Technical Department in London to look after heavy organic chemicals, and in 1934 he became a delegate director of the I.C.I. Dyestuffs Division. In 1936, I.C.I. started a project on pharmaceuticals with which Dr. Hepworth has been concerned ever since. When Imperial Chemical (Pharmaceuticals) Ltd. was formed in 1942, Dr. Hepworth became a delegate director and, later, delegate managing director.

In 1945 he led the British Mission on Pharmaceuticals to Germany and, in 1950, he was awarded the O.B.E. For about 25 years Dr. Hepworth has represented I.C.I. on the Group 'B' Committee of the A.B.C.M., of which he was chairman for some years.

★ **Mr. A. C. H. Cairns**, B.A., B.Sc., A.R.I.C., was appointed to the board of Joseph Crosfield & Sons Ltd. on October 1, 1953. Mr. Cairns, who is 43 and an old boy of Whitgift School, Croydon, began his chemical career by obtaining an honours degree in chemistry at St. John's College, Oxford. From there he joined the laboratory of Lever Bros., Port Sunlight, Ltd., passing through the works and Central Technical Department before leaving for war service at the R.O.F., Pembrey, in 1941. His academic achievements found an outlet in the field of explosives and it was research and investigation into these which resulted in his being appointed Chief Technical Assistant to the Director of Ordnance Factories. Release by the Ministry was followed by his appointment as technical officer to the U.K. soap executive of Unilever Ltd., after which, in 1947, Mr. Cairns became chemical sales manager of Joseph Crosfield & Sons Ltd., being appointed to the board of Industrial Soaps Ltd. as sales director in 1950. Mr. Cairns has also been appointed to the board of William Gossage & Sons Ltd.

GERMANY

New petroleum chemicals plant

Construction of a plant for the manufacture of polythene and ethyl benzol from crude oil, the first of its kind in West Germany, will be started near Cologne shortly.

The plant, founded by the Badische Anilin und Soda Fabrik A.G., Ludwigshafen, and the German Shell Co., Hamburg, will process refinery gas to be supplied from an adjacent crude oil refinery. Production is expected to begin in 1955.

FRANCE

'Terylene' production licence granted

Societe Rhodiaca, of Lyons, makers of nylon and acetate rayon, are to manufacture and sell *Terylene* polyester fibre in France under licence from I.C.I.

This announcement follows the news, published in *CHEMICAL & PROCESS ENGINEERING* last month, that *Terylene* is to be produced in Italy by Montecatini, and is a further illustration of the world-wide interest in the new synthetic fibre.

Terylene was discovered by J. R. Whinfield and J. T. Dickson in the laboratories of the Calico Printers' Association in 1941. I.C.I. acquired the exclusive world rights for the fibre, except for the U.S.A., in 1947.

I.C.I.'s plans for bigger British production are making rapid progress and the building of the large new *Terylene* plant at Wilton, North Yorks, is up to schedule. This plant should be ready by the end of 1954 and in production in 1955.

HOLLAND

£1 million plant will make new insecticides

Scheduled for immediate construction and for completion by mid-1955 a new plant at Shell's Pernis (Rotterdam) refinery in Holland will make available for worldwide distribution two new insecticides, aldrin and dieldrin, which have already had international success.

With production hitherto confined to the U.S.A., the use of these products in many countries has been limited because of currency considerations. However, quite large quantities have been made available in certain countries through the U.S. Government aid programmes, particularly for locust control and public health applications. The plant to be erected in Holland, at an estimated cost of more than £1 million, will make these materials more readily available throughout the world. In view of the importance of these two products in agriculture and public health, plans have been laid to manufacture them in such quantities as will satisfy not only Shell's own requirements but also the needs of other insecticide manufacturers wishing to use aldrin and dieldrin as the base material for their own products.

A comprehensive development programme has been carried out with aldrin and dieldrin on a worldwide basis and has confirmed the unique value of these materials for the control of soil insects, cotton pests, locusts, ants and many other insects. In particular, the extreme potency and long residual action of dieldrin make this compound invaluable for public health work. Unlike other insecticides, it will control both the Anopheline and Culicine mosquitoes, which are respectively the carriers of malaria and filariasis. Their great biological activity makes it possible to use these insecticides at application rates which are a mere fraction of those needed for other insecticides such as DDT and BHC.

Aldrin attracted worldwide attention in 1951 when the Iranian Government appealed for help in combating its worst locust plague in 80 years. Under the T.C.A. (now Mutual Security Administration) programme, 13 tons of aldrin were flown to Iran and applied at the recommended strength of only 2 oz. per acre. Within 24 hours 98% of the insects were killed, the plague checked and the threat of famine averted.

The terms 'aldrin' and 'dieldrin' are now common names. They were coined from the well-known chemical synthesis, the Diels-Alder reaction, used in their manufacture.

NORWAY

Paper industry research

King Haakon recently laid the foundation stone for a new building in Oslo to be used by the Norwegian paper industry's research institute. On this occasion the King received a book giving the history of the Norwegian industry. According to

The Leonard Hill Technical Group—November

Manufacturing Chemist—Manufacture of Writing Inks, Chemotherapy and Selective Toxicity, 2; The Structure of Coenzyme A; Animal Health Products; Manufacture of Acetarsol; Progress Reports: Economic Poisons, Perfumery and Essential Oils.

Food Manufacture—Processing Vegetables in the U.S.A.; The Measurement of Air Concentration in Large Steam Spaces During Air Venting; The Irish Jam and Marmalade Industry.

Fibres—Silicone Finishes in the Textile Industry; Survey of Fibre End Use Developments; Synthetic Detergents in the Wool Textile Industry; New Dyeing Processes; Chemicals for Use in Synthetic Fibre Manufacture, 3.

Paint Manufacture—How Inks Dry, 1; Paint Technology and the Law, 1; How to Solve Materials Handling Problems in the Medium-sized Paint Factory, 2; Canadian Raw Materials Report; The Determination of Particle Sizes; Lead Cyanamide; Visit to I.C.I.; Pigments Progress Review, 1953.

Petroleum—Oil Productions in Alberta; Petroleum Chemicals in Canada; Oils and Chemicals; Choice of Jet Fuels; Petroleum Abstracts.

Atomics—Printed and Potted Electronic Circuits; Radio-isotopes in the Measurement of Engine Wear; Periodic Structures, Rhythmic Chromatograms and Radio-isotopes.

Building Digest—A New Method in Concrete House Construction.

Muck Shifter—Almendaras River Tunnel at Havana, Cuba; Recent Extension to the Pennsylvania Turnpike; Prestressed Concrete Railway and Conveyor Bridge, Calverton.

World Crops—Nutrition and Agriculture in Indonesia; Hemp; Report of the International Cocoa Conference.

this, the Norwegian paper industry has today 90 factories which have an annual production of 700,000 tons of woodpulp, 550,000 tons of sulphite cellulose, 100,000 tons of sulphate cellulose, about 550,000 tons of paper, cardboard, pasteboard, etc., and 100,000 tons of wallboard. The new institute, which is expected to be completed in about a year's time, is financed to a great extent by funds raised from the export premium on its produce.

YUGOSLAVIA

Paper industry expansion

The Yugoslav paper industry is expected to be self-sufficient from 1955 onwards. A new paper factory with an annual capacity of 24,000 tons is being constructed at Videm-Krsko. In Maglaj (Bosnia) another plant for soda pulp production is being erected.

Monthly paper, cardboard and pulp production now amounts to around 6,000 tons. About 3,500 tons of paper have already been exported this year. On the other hand, Yugoslavia has so far imported 7,000 tons of newsprint from Austria and Finland and has also had to buy most of her soda pulp requirements in Austria.

AUSTRALIA

Nordberg representative's death

Nordberg Manufacturing Co. has announced with deep regret the death of Mr. Howard Middleton, its representative in Sydney, Australia.

Administration of Mr. Middleton's office in Martin Place at Sydney will continue as will the services of the Nordberg distributors, Noyes Bros. (Sydney) Ltd., Noyes Bros. (Melbourne) Ltd. and Perkins (Australia) Pty. Ltd.

UNITED STATES

Nuclear engineering studies

An agreement which opens the way for immediate operation of the first university-owned nuclear reactor in the United States has been signed between the Atomic Energy Commission and the North Carolina State College, Raleigh, North Carolina. Under the terms of the contract, the A.E.C. will loan the college enough fissionable uranium 235 to fuel the university's 'Raleigh Research Reactor.'

Provision of the fissionable material, or fuel, for the new reactor culminates a project which has been under way since June 1950 when the college, under contract to the A.E.C., initiated design and construction of a low-powered research reactor. The reactor assembly, housed in a special building on the campus, is now complete and most of the pre-operational testing also has been completed. The reactor, which will begin operations as soon as the fissionable material is received from the A.E.C., was designed and built completely with University of North Carolina funds available to the college and, consequently, is owned by the institution.

One of its major purposes will be to supply reactor experience to undergraduate and graduate students in nuclear engineering. A programme of research on the reactor itself is scheduled for the first year of its operation, after which the emphasis will shift to the use of radiations and radioactive isotopes produced by the reactor in numerous research activities of the college and neighbouring institutions.

North Carolina State was the first educational institution to approach the A.E.C. with a proposal to design, build and operate a research reactor and its proposal was the first one accepted by the agency. In making the fissionable material available to the college, the A.E.C. acted under the Atomic Energy Act of 1946, which permits the distribution of such materials for research and development activities, and for medical therapy. The A.E.C. may terminate the contract should national security considerations demand recall of the fissionable materials supplied under the agreement.

Kraft paper expansion plan

A \$4½ million expansion programme has been announced by the St. Regis Paper Co. for its kraft manufacturing centre at

Pensacola, Florida. Scheduled for completion by next July, the programme is designed to increase the flexibility of the centre so that it will produce bleached and unbleached grades of kraft paper for a variety of uses.

Phenol and acetone plant for New Jersey

The Hercules Powder Co. is venturing into new fields with an \$8 million plant in New Jersey which will produce phenol and acetone. This plant, concerned with chemicals widely used in plastics and synthetic fibres, is scheduled to be operating in mid-1954.

The company also has under pilot-plant study and development a chemical product used in polyester fibres such as *Terylene*.

Special steel for sulphate digesters

A special steel for sulphate digesters for the paper and pulp industry is now being made by Lukens Steel Co. The steel is of the rimming type, similar to the rimming steels used in digester applications some years ago. Lukens claim, however, that the new material combines the desirable qualities of old-type rimming steels with the characteristics necessary for easy fabrication of the heavy-gauge metals used in this application. It can be supplied in a wide range of plate widths, thicknesses and lengths and of pressed-head sizes and shapes.

New way to purify radium

A new way to purify radium by a process called 'precipitation from homogeneous solution' has been developed by a team of Monsanto Chemical Co. research chemists at the company's Mound Laboratory, Miamisburg, Ohio. According to Dr. M. L. Salutsky, Dr. J. G. Stites, and Mr. E. F. Joy, all of the Monsanto atomic energy laboratory, the new process is a vast improvement over that used by Marie and Pierre Curie who discovered radium in 1898. Commercial producers today still use the process prescribed by the Curies to purify this valuable and dangerous material.

The Mound Laboratory method replaces the most difficult portion of the Curie process in which the radium is separated from the chemically similar element, barium. Radium and barium occur together in nature and are very difficult to separate because they are so much alike chemically. The important difference between them is that radium is radioactive and barium is not. For this reason the Atomic Energy Commission is interested in pure radium, with the barium removed.

After all of the other impurities have been removed, radium and barium remain together in solution. The Monsanto scientists have succeeded in forming the necessary chemicals within this solution which cause the radium to be separated from the barium much more readily.

The 'precipitation from homogeneous solution' method they have devised is

faster and uses fewer steps than the method of the Curies, which is called 'fractional crystallisation.' Their process to separate the radium from the barium required many weeks and many separate steps.

It is claimed that by the new method commercially pure radium can be separated in a few days from a mixture containing only ten parts of radium per million parts of barium.

BRAZIL

Fertiliser reserves to be exploited

The Government of the state of Minas Geraes has decided to exploit the apatite (calcium phosphate) reserves in the Araxa area. The reserves, estimated at over 100 million tons, were discovered in 1936, but, despite many private offers for commercial exploitation, have not been used. The decision to utilise them now has been taken because of the lack of adequate fertiliser supplies in the state.

INDONESIA

Caustic soda project

The Indonesian Government is to establish a caustic soda plant at Waru, near Surabaya, at a cost of 60 million rupees. The plant will be completed in 1954 and will start production early in 1955.

The new plant will be able to produce one-fifth of the country's soda requirements, which average about 15,000 tons p.a. The machinery for the factory has been ordered in Japan and will be installed by Japanese experts.

INDIA

Chemical enterprise has Swiss backing

A joint Swiss/Indian concern for the production of heavy chemicals has been founded under the name of Heavy Chemicals Ltd., according to a report in the Swiss *Neue Zuercher Zeitung*. The new concern, which has its office in Madras, will erect a factory in Tuticorin for the production of electrolytic caustic soda, hypochloride, titanium tetrachloride, titanium dioxide and ferrosilicide. A final daily capacity of 10 tons of caustic soda is scheduled.

The equipment for the factory will be supplied by two Swiss firms, the Krebs & Co. A.G., Zurich, and the von Roll A.G., Zurich. The authorised capital will be 5 million rupees. Of this, 3.5 million will be taken over by the Swiss firms and 1.5 million will be offered to the public in the form of preference shares.

MEETINGS

Institution of Chemical Engineers

November 11. 'Perforated Plates in Liquid-Liquid Extraction (Toluene-Diethylamine-Water System),' by F. H. Garner, S. R. M. Ellis and D. W. Fosbury, 6.30 p.m., The University, Edmund Street, Birmingham.

November 14. 'The Interpretation of Minimum Reflux Conditions in Multi-component Distillation,' by J. S. Forsyth and N. L. Franklin, 3 p.m., College of Technology, Manchester.

November 18. Film: 'The Stanlow Story,' introduced by E. Le Q. Herbert, 5.30 p.m., Caxton Hall, London, S.W.1.

Graduates' and Students' Section

November 12. 'Works Study as an Instrument of Control in Industry,' by W. Kenyon, 6 p.m., College of Technology, Sackville Street, Manchester 1.

November 13. 'Some Aspects of the Absorption of Silicon Tetrafluoride Gas in Water,' by Dr. L. H. Whynes, 6.30 p.m., Caxton Hall, London, S.W.1.

Society of Chemical Industry

November 12. 'Three-Dimensional Chemistry,' by A. F. Wells, 7.30 p.m., Town Hall, Preston. Joint meeting with the R.I.C.

November 16. 'Chemical Aspects of Textile Technology,' by C. S. Whewell, 7 p.m., Technical College, Bradford.

November 18. 'Some Reflections on the Pharmaceutical Industry,' by H. Hepworth, 7.30 p.m., Golden Lion Hotel, Stirling.

November 19. 'Production, Fabrication and Properties of Titanium,' by W. Baker, 7.30 p.m., Robert Gordon's Technical College, Aberdeen. Joint meeting with the Chemical Society and the R.I.C.

November 19. 'The Manufacture of Chemicals from Petroleum,' by J. L. Edgar, 6.30 p.m., Chemistry Lecture Theatre, The University, Manchester. Joint meeting with the R.I.C. and the Chemical Society.

November 19. 'Some Intermolecular Compounds,' by H. M. Powell, 7.45 p.m., 'Appleby' Lecture Theatre, The University, South Road, Durham. Joint meeting with the R.I.C. and the Chemical Society.

November 24. 'The Changing Pattern of Plant Design in the Basic Chemical Industries,' by S. Robson, 7 p.m., Chemistry Lecture Theatre, The University, Liverpool.

November 26. 'Synthetic Crystals,' by R. C. Chirnside, 7 p.m., Chemistry Department, Technical College, Sunderland. Joint meeting with the Society of Glass Technology.

December 4. 'Some Recent Studies in Pyrolysis,' by P. D. Ritchie, 7.15 p.m., Royal Technical College, Glasgow.

December 7. 'Ten Years Hence: The Promise of Chemical Technology in Great Britain,' by R. F. Goldstein, 6.30 p.m., Chemical Society Rooms, Burlington House, Piccadilly, London, W.1.

Chemical Engineering Group

November 10. 'Impulse Rendering Process,' by I. H. Chayen and D. R.

Ashworth, 5.30 p.m., Geological Society Rooms, Burlington House, Piccadilly, London, W.1.

December 3. 'Metallurgical Trends of Interest to the Chemical Industry,' by L. Rotherham, 7 p.m., Department of Chemistry, The University, Bristol. Joint meeting with the Institute of Metals.

Corrosion Group

November 13. Symposium on Cathodic Protection: 'Canadian Marine Vessels,' by K. N. Barnard; 'Ships and Establishments of the Royal Navy,' by J. T. Crennell; 'Economic Aspects,' by D. H. Lewis and O. C. Mudd; 'Effect of Composition of Magnesium Anodes,' by M. Oudeman; 'Engineering Design,' by K. A. Spencer; 'Development of Cathodic Protection in Belgium,' by A. Weiler; 'Corrosion Control in the Middle East,' by W. C. R. Whalley; 9.45 a.m., Institution of Electrical Engineers, Savoy Place, London, W.C.2.

Plastics and Polymer Group

November 25. 'Vinyl Emulsion Polymers and their Use in Coatings,' by C. E. Hollis and J. H. W. Turner, 7 p.m., Royal Society of Tropical Medicine and Hygiene, Manson House, 26 Portland Place, London, W.1.

Chemical Society

November 19. 'Some Applications of the Separation of Large Molecules and Colloidal Particles,' by Prof. A. Tiselius, 7.30 p.m., Lecture Theatre, Institution of Civil Engineers, London, S.W.1.

November 19. 'The Mechanism of the Reaction between Gases and Solids,' by Dr. J. S. Anderson, 5 p.m., Chemistry Lecture Theatre, The University, Liverpool. Joint meeting with the R.I.C., S.C.I. and the British Association of Chemists.

November 19. 'Electron Transfer Reactions,' by Prof. F. S. Dainton, 5.45 p.m., Department of Chemistry, University College of North Wales, Bangor.

November 20. 'The Scope and Application of X-ray Methods in Organic Chemistry,' by Prof. J. Monteath Robertson, 6 p.m., University College, Swansea. Joint meeting with the R.I.C.

November 26. 'Infra-red Spectroscopy and Chemical Problems,' by Dr. H. W. Thompson, 7.30 p.m., Chemistry Lecture Theatre, The University, Sheffield. Joint meeting with the R.I.C.

November 27. 'Contributions of Optical Activity to the Study of Some Chemical Reactions,' by Dr. J. Kenyon, 5.30 p.m., Chemistry Building, King's College, Newcastle-on-Tyne.

Royal Institute of Chemistry

November 17. 'The Manufacture and Uses of Hydrogen Peroxide,' by W. S. Wood, 7 p.m., Battersea Polytechnic, London, S.W.11. Joint meeting with the Chemical Society.

November 19. 'Some Recent Advances in Fluoride Analysis,' by B. J. MacNulty, 7 p.m., Medway Technical College, Gardiner Street, Gillingham.

November 23. 'Synthetic Soil Conditioners,' by R. C. Tincknell, 6.45 p.m., Woolwich Polytechnic, London, S.E.18. Joint meeting with the Chemical Society.

November 25. 'Corrosion in Action,' by E. J. Vaughan, 6.30 p.m., Dartford Technical College, Lowfield Street, Dartford.

November 27. 'Some Aspects of the Chemistry of Phenols and Inclusion Compounds,' by Prof. W. Baker, 8 p.m., University Chemical Laboratory, Cambridge. Joint meeting with Chemical Society.

Fertiliser Society

November 13. Visit to I.C.I. Billingham Works; 'Nitrophosphate,' by Dr. W. d'Leny, 11.30 a.m.

November 26. 'Fertiliser Investigations in the Netherlands,' by Dr. E. G. Mulder, 2.30 p.m., Lecture Hall, Geological Society, Burlington House, Piccadilly, London, W.1.

Incorporated Plant Engineers

November 10. 'Illumination and Factory Lighting,' 7.15 p.m., Engineers' Club, Albert Square, Manchester.

November 11. 'An Introduction to Cost and Works Accounting for the Works Engineer,' by S. H. Alloway, 7 p.m., Demonstration Theatre, East Midlands Gas Board Showrooms, Parliament Street, Nottingham.

November 18. 'Heat Transfer,' by R. A. Brecknell, 7 p.m., Scottish Building Centre, 425-427 Sauchiehall Street, Glasgow, C.2.

November 19. 'Electrical Hazards,' by D. A. Picken, 7.30 p.m., Grosvenor Hotel Lord Street, Blackburn.

November 30. 'Some Recent Applications of Electronics in Industry,' by R. H. Wheat, 7.30 p.m., The University, Leeds.

Institute of Metals

November 10. 'The Development of Metallic Arc Welding and Electrodes During the Past Half-Century,' by E. Flinham, 7.15 p.m., College of Technology, Byrom Street, Liverpool. Joint meeting with the Institute of Welding.

November 11. 'The Properties and Applications of Spheroidal Graphite Cast Iron,' by A. B. Everest, 6.30 p.m., Lecture Room, Central Library, Manchester.

November 19. 'Metallurgical Problems Connected with the Development of Atomic Energy,' by L. Rotherham, 7 p.m., Liverpool Engineering Society Rooms, The Temple, Dale Street, Liverpool.

November 19. 'Recent Advances in Electro-Deposition,' by J. W. Cuthbertson, 6.30 p.m., Imperial Hotel, Temple Street, Birmingham.

Institute of Petroleum

November 11. 'Paint in the Petroleum Industry,' by Dr. H. B. Footner, 5.30 p.m., 26 Portland Place, London, W.1.

Institute of Welding

November 19. 'The Design of Arc Welded Structures,' 7.15 p.m., Sun Hotel, Chatham.

Institution of Mechanical Engineers

December 4. 'Comparative High-temperature Properties of British and American Steels,' by W. B. Bardgett; 'A Critical Examination of Procedures Used in Britain and the United States to Determine Creep Stresses for the Design of Power Plant for Long Life at High Temperatures,' by R. W. Bailey, 5.30 p.m., Storey's Gate, St. James's Park, London, S.W.1.

Institution of the Rubber Industry

November 9. 'Influence of Organic Chemicals in Rubber Manufacture,' by F. A. Jones, 5 p.m., James Watt Institute, Gt. Charles Street, Birmingham.

November 9. 'Recent Developments in Rubber Compounding Ingredients,' by J. Mason, 7.15 p.m., Bull and Royal Hotel, Church Street, Preston.

CHEMICAL & PROCESS ENGINEERING

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